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FRESNO STATE NORMAL SCHOOL

Studies in Elementary Agriculture

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BY

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INTRODUCTION.

The subject of Agriculture has won a permanent place in the common school curriculum. It is now classed along with music, drawing and manual training as one of the special subjects. In a few more years agriculture and domestic science will form the foundation upon which the new curriculum of the common school will be built. "But what of the cultural subjects?" I hear the multitude ask. Those of the old order must yield to those of the new; to that culture that teaches human minds to conceive and human hands to put in order a beautiful home, whether it be a cottage or a large modern dwelling; to that culture that gives woman complete knowledge of the child mind and the child body to aid mother love in rearing cultured men and women; to that culture that teaches men to lay out and to build beautiful roads and to develop beautiful villages and school grounds; to that culture that teaches men and women to love God's great out-of-doors better than the man-made cities. When the subjects of agriculture and domestic science come in their fullness they will bring real culture.

The studies of the following pages constitute part of the laboratory course given with the subject of agriculture in the Fresno State Normal. They are designed to prepare teachers for presenting the subject of agriculture in the rural school. They are not predigested and ready for presentation to the child with teacher's story, introduction, description and conclusion complete, but are outlines to direct the student in preparing the studies for presentation to the child. The work of the student is complete only when, through his own efforts, each study is ready, from the teacher's story to the conclusion, for presentation to school children. Through the preparation of these studies the student gets a broad knowledge of elementary agriculture, experience in preparing subject matter and material for presenting agricultural studies and nature study lessons, and begins to find, understand, and appreciate the beauty of all things out of doors.

Acknowledgment. The author claims but little originality for the following studies. Only a few of them are his own. Every available source has been drawn upon for these studies—Government Bulletins, Textbooks, Agricultural College, Experiment Station and Normal School Bulletins. Something like a hundred and sixty studies have been given a three years' test in the laboratory, and the following chosen as being worth while. Mr. C. L. Flint, Instructor in Agriculture, Fresno State Normal, and A. E. Balch, Deputy County Superintendent of Public Schools of Fresno County, have given many valuable suggestions for the studies. The following publications have furnished many suggestions for the final preparation of this series: *Elements of Agriculture*, by

G. F. Warren; *Agriculture Through the Laboratory and School Garden*, by C. R. Jackson and Mrs. L. S. Daugherty; *First Course in Biology*, by L. H. Bailey and Walter M. Coleman; *Publication No. 34 of the University of California Syllabus Series of the Department of Agricultural Education*, by C. A. Stebbins; *Circular No. 58 of the University of California College of Agriculture*, "Experiments with Plants and Soils in Laboratory, Garden and Field," by Frank E. Edwards; *Farmers Bulletin No. 408 of the U. S. Department of Agriculture*, "School Exercises in Plant Production," by Dick J. Crosby and *Laboratory Manual in Biology*, by Richard W. Sharpe.

SOLON W. CUNNINGHAM.

SPECIAL APPARATUS.

Every rural school should be equipped with some little apparatus that will aid in presenting the subjects of agriculture and nature study.



Fig. No. 1. Inexpensive apparatus every rural school should possess.

The following suggested list is not very expensive and would make it possible for the teacher to present interestingly many practical things in the study of insects, plants and soils. (Fig. No. 1.)

The prices given are those quoted by the Braun-Knecht-Heimann Co., 575-584 Mission street, San Francisco,

at the time of the publication of this bulletin.

Harvard trip scale -----	\$6 65
Weights (500 gram piece to 1 gram) -----	2 50
Gasoline burner (adjustable laboratory form) -----	5 00
Ring support, base 4" x 6", rings 3", 4" to 5" in diameter -----	1 00
2 Dissecting scopes -----	5 00
2 Graduate glasses, 250, c.c. -----	2 20
1 Set dissecting tools -----	1 50
2 Doz. test tubes -----	60
2 Test tube clamps -----	80
1 Doz. eight ounce bottles, plain flint glass -----	45
$\frac{1}{2}$ Doz. pipestem triangles (medium) -----	40
2 Test tube clamps, Stoddard's -----	30
2 Thermometers -----	1 10
1 Doz. porcelain crucibles, Royal Meissen -----	1 20
Total -----	\$28 70

FOREWORD TO THE TEACHER.

You are interested in the study of agriculture and wish to make the subject more interesting to the children. The following studies open a way for you to do so. They mean a little extra work and additional reference reading on your part but the results obtained will compensate many times for the extra work. This bulletin is a guide for the teacher and should not be given to grade school children as a laboratory manual. Neither should the studies be substituted for either the school garden or the home garden, but should correlate with and supplement the garden work and the study of the textbook.

The graduates of the Fresno State Normal School are trained to use these studies. The teacher who has not studied the series should do so before outlining the work for the class. If the class be large, divide the children into groups of four to six and have the groups take turns in preparing the studies under your direction as demonstration studies for the class. The remainder of the class may observe the work, and through the writing of a short essay tell what was used and describe each step in preparation of the study.

Your school will not possess the equipment that makes possible the taking up of all of these studies. *However, take special note of the fact that the big majority of them do not require chemicals and special apparatus. The studies marked with the star can be carried out with tin cans, pie tins, water glasses and small wooden boxes (cigar boxes are excellent).* All of these can be collected by the children.

For the series of studies upon the soil, a grain sack of each of the following types of soil should be obtained, and half of each type put where it will dry and keep dry: sand, loam, clay and humous soil. (The term "humous soil" as used in this publication means a soil rich in decayed and decaying plant matter.)

Should the taking up of these studies be the first of this sort of work you have done, you will find that, through your lack of experience in handling such work, some of the studies will not give the results they should. Do not let this discourage you. Study the situation, check over your work, look for the cause of failure and work out the study again and still again if necessary. The Faculty of the Department of Agriculture of the Fresno State Normal School is ready at all times to give any aid you may ask in this work.

ORIGINAL WORK FOR THE STUDENT TEACHER.

Prepare from each of the following studies a lesson outline for seventh and eighth grade children. The following outline will give you an idea for a general plan.

Study Number One.

- I. Illustrative material.
 1. Pictures of a stream showing water-worn rocks and stream-cut banks.
 2. Rounded pebbles and rocks from a stream.
 3. If a stream be convenient, make plans to visit it.
- II. Order of presentation.
 1. Perform "Study Number One."
 2. Show pictures and smoothed and rounded rocks and pebbles.
 3. Visit a stream if possible.
- III. Teacher's story.
 1. Describe quite fully the work of the creek.
 2. Tell how the stream got its rocks and pebbles.
 3. Tell what the stream is doing with them.
 4. Tell what finally becomes of them.
 5. Contrast normal stream work with its work at flood time.

Books for Reference Reading.

1. Principals of Botany; Bergen and Davis.
2. Botany for Schools; Atkinson.
3. Practical Botany; Bergen and Caldwell.
4. Elements of Agriculture; Warren.
5. Principles of Agriculture; Bailey.
6. First Course in Biology; Bailey and Coleman.
7. Principles of Agriculture Through School and Home Garden; Stebbins.
8. Agriculture for Schools of the Pacific Slope; Hilgard and Osterhout.
9. Handbook of Nature Study; Comstock.
10. Nature Study; Hodge.
11. Nature Study; Cummings.
12. Soils; Hilgard.
13. Soils; King.
14. The Fertility of the Land; Roberts.
15. Applied Biology; Bigelow.
16. Cyclopedia of American Agriculture; L. H. Bailey.

SOIL STUDIES.

*Study Number One.

Water Disintegrates Rocks.

Apparatus—Heavy glass, pint bottle, stopper for same.

Materials—Small pebbles, water.

Procedure—Wash a half dozen to a dozen of the pebbles until they are clean. Place them in the bottle, fill the bottle two-thirds full of water, cork tightly and shake vigorously for ten minutes. (Let the pupils take turns in shaking the bottle.)

Note the clear water taking on a change of appearance as the shaking proceeds. (Fig. No. 2.)



Fig. No. 2. Illustrating study number one.

Questions—1. What caused the clear water to get muddy? 2. Where is this process being carried on in nature?

NOTE.—Illustrate what the student has seen taking place here with smooth and rounded stones taken from the bed of a stream.

*Study Number Two.

Water Disintegrates and Transports Soils.

Apparatus—Spade and water sprinkler.

Materials—Soil, large pebbles, gravel and sand.

Procedure—In an out-of-the-way place throw up a cone shaped pile of soil about two feet high and six feet in diameter at the base. Mix in the soil as it is being piled, quite thoroughly, pebbles, gravel and sand. Sprinkle the mound a half dozen times as it is being built. Allow the mound to settle for a week or ten days, sprinkling it occasionally to harden and pack the surface.

With the sprinkler, sprinkle water slowly on the top of the mound. Note how little streams are cut, how this miniature hill is being worn down, how the soil is being deposited at the base of the mound.

Make comparison of the work of water done here under the pupils' observation to the work of water under natural conditions. (Figs. No. 3 and No. 4.)



Figs. Nos. 3 and 4. Illustrating study number two.

Questions—1. How have the alluvial plains at the base of mountain ranges been formed? 2. How have our river valleys and canyons been formed? 3. Why are the beds of our streams and rivers composed chiefly of rocks, gravel and sand? 4. If the sprinkling were continued long enough what would happen to the mound? 5. Why is our best farming land found in the river valleys?

*Study Number Three.

The Transporting Power of Water.

Apparatus—Four ounce bottle, scales and weights.

Materials—To be obtained.

Procedure—Weigh the four ounce bottle. From an irrigation ditch or natural stream, in which the water is carrying a great deal of material in suspension, fill the bottle. Dry the outside of the bottle, and weigh it and its contents. Set it aside until the water becomes clear. Carefully pour into an evaporating dish all of the water possible without losing any of the sediment. Set the bottle aside or put into the drying oven until the sediment is dry, then take a third weighing. Put the evaporating dish over a burner and evaporate off the water. Note results. (Fig. No. 5.)

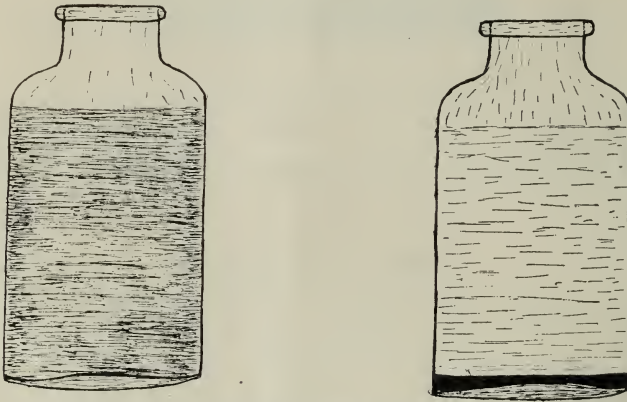


Fig. No. 5. Illustrating study number three.
1—Muddy water from irrigation ditch.
2—Sediment separated by settling.

Calculate the per cent of sediment.....
Weight of bottle
Weight of bottle and water.....
Weight of bottle and dry sediment.....
Weight of water
Weight of dry sediment
Per cent of sediment.....

Questions—1. After evaporation, what was left in the evaporating dish? 2. In what two ways does water carry material? 3. What material is of direct food value to the plant? 4. Does the material in suspension in irrigation water in any way benefit the land? 5. Are there any conditions under which the material in solution in irrigation water might harm the land?

*Study Number Four.

The Assorting Power of Water.

Apparatus—Pint fruit jar, lid and rubber for same.

Materials—Sand, loam, clay and gravel and water.

Procedure—Put a tablespoonful each of sand, clay, loam and gravel into the jar. Fill the jar two-thirds full of water. Put the lid on the jar and shake vigorously, giving the water a rapid whirling motion in the jar. Set the jar aside until the water becomes clear. Note the arrangement of the earth material in the bottom of the jar. (Fig. No. 6.)

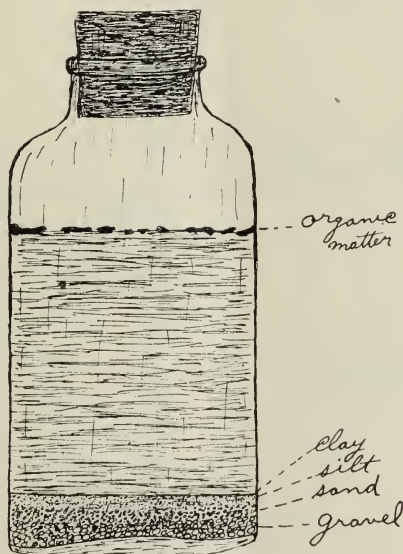


Fig. No. 6. Illustrating study number four.

Questions—1. What is the cause of the arrangement of soil in the jar? Explain. 2. Have you ever noticed this being done by running water under natural conditions? Explain. 3. What is done with the material carried by running water when a creek or river is at flood tide?

Study Number Five.

Chemical Action of Carbon Dioxide.

Apparatus—Florence flash, thistle tube, right angle tube, two-hole stopper, two water glasses, rubber tube, pneumatic trough.

Materials—Marble or limestone, lime water.

Procedure—Set up the apparatus for the generation of carbon dioxide. (Fig. No. 7.) With the rubber tube bubble the gas through a third of a glass of lime water. Note what takes place in the lime water. Account for the change you see.

Continue to bubble the gas through the lime water until you get clear water again.

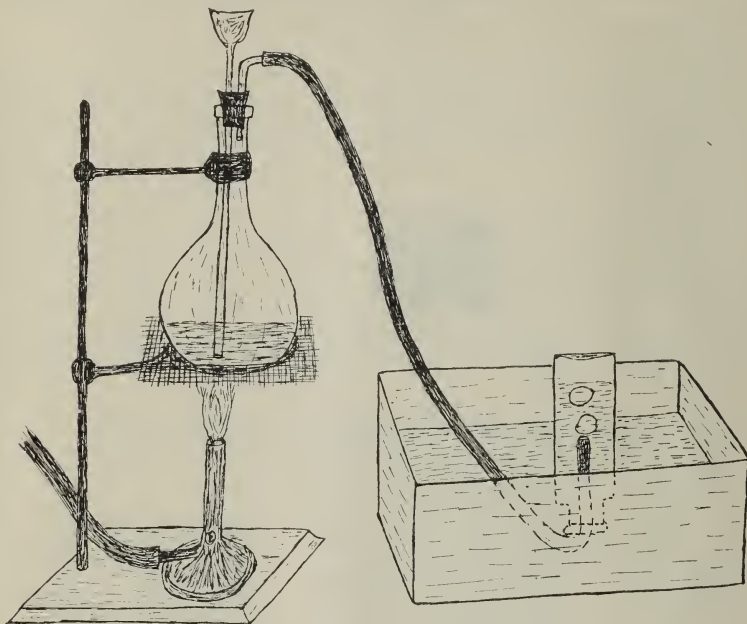


Fig. No. 7. Illustrating apparatus used in study number five.

Questions—1. What caused the changes seen above? 2. Is carbon dioxide a soil destroyer or a soil builder? Explain. 3. How is the above process carried on under natural conditions? Explain fully.

Study Number Six.

Water in Soils.

Apparatus—Scales and weights, Bunsen burner, 4 porcelain crucibles.

Materials—To be obtained.

Procedure—Collect under field conditions samples of loam, clay, sand and humous soil.* Carefully weigh each of the four crucibles. In one weigh a ten gram sample of clay, in another loam, another sand, and in the fourth humous soil. Dry in an oven at 96 degrees centigrade for 24 hours. Reweigh each crucible with sample.

Compute the per cent of water in each soil.

Weight of crucible _____
 Weight of crucible and soil _____
 Weight of soil _____
 Weight of crucible and dried soil _____
 Weight of dried soil _____
 Weight of water _____
 Per cent of moisture _____

Questions—1. Which soil contained the most water? Explain why. 2. How is this water held in the soil? 3. In which soil would an equal per cent of water be of most benefit to the plant? Explain.

*In this publication the term "humous soil" is used to signify a soil rich in decayed and decaying plant matter.

*Study Number Seven.

The Illustration of Capillarity.

Apparatus—Jelly glass, 4" x 4" square of cardboard, half dozen pieces glass tubing of different size bore four to six inches in length.

Materials—Water, red or blue ink.

Procedure—Put a half dozen drops of ink in a glass one-fourth full of water. Make four perforations in the cardboard and place the glass tubes through them, letting each tube stand on the bottom of the glass and the cardboard rest on the top of the glass. Note the height the colored water rises in each tube. Illustrate by drawing. (Fig. No. 8.)

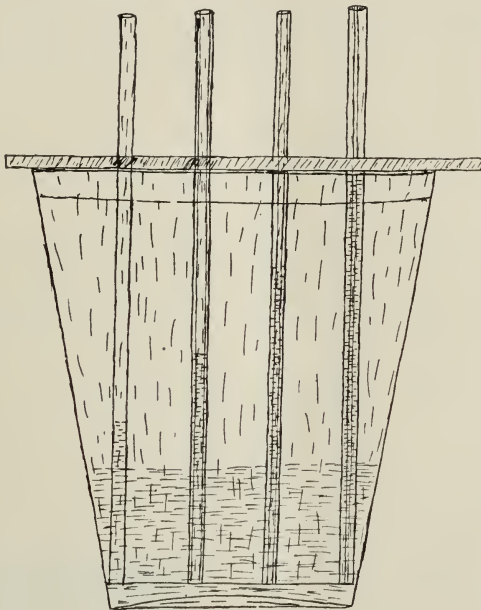


Fig No. 8. Illustrating study number seven.

Questions—1. In which tube does the water rise the highest? 2. In which does it rise the least? 3. In what sort of soils would water rise the highest by capillarity?

*Study Number Eight.

The Capillarity of Soils.

Apparatus—Four student lamp chimneys, rack and six pie tins, foot rule, cheesecloth, four glass tubes of one inch diameter five feet long, potato masher.

Materials—Clay, loam, sand and humous soil.

Procedure—Over the top of each lamp chimney and glass tube tie a square of cheesecloth. With the potato masher and pie tin thoroughly pulverize a sample of each type of soil. Fill the lamp chimneys

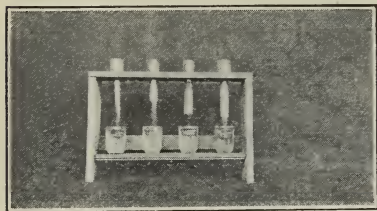


Fig. No. 9. Illustrating study number eight.

The soils are from right to left: sand, sandy loam, humous soil and clay.

Jar each down until the soil is packed firmly. Suspend all of the lamp chimneys in the rack with the lower end of each hanging in a glass of water, or stand them in a pie tin of water. (Fig. No. 9.) Renew the water supply as fast as each soil takes it up. At fifteen minute intervals measure the height to which the water has risen in each lamp chimney. Continue until four measurements have been taken or the water reaches the top. In each case note the exact time it takes the water to get to the top. After 72 hours measure the height of the water in the five foot tubes.

Compute the rate of capillarity for each type of soil.

Final height of capillary water-----

Time required in reaching height-----

Rate of capillarity per hour-----

Questions—1. In which soil did water rise the fastest? 2. In which soil did water rise the slowest? 3. How do you account for the different rates of capillarity? 4. What is the relation between capillarity and water loss by evaporation? 5. What is the relation between capillarity and the water needs of the plant?

*Study Number Nine.

The Porosity of Soils.

Apparatus—That used in Study Number Eight.

Materials—Sand, clay, loam, humous soil, and water.

Procedure—Fill the lamp chimneys as in Study Number Eight except that you fill only to the bulge at the base of the chimney. Suspend the chimneys in the rack and place an empty water glass under each. (Fig. No. 10.) Fill the bulge of each chimney with water, taking note of the time as you do so. Keep the bulge of the chimney filled with water until it drips at the bottom. Measure the depth to which the water has percolated every fifteen minutes.

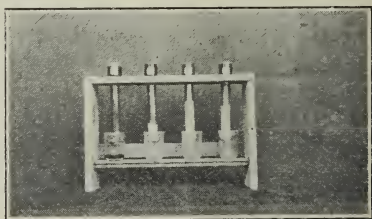


Fig. No. 10. Illustrating study number nine.

The soils are from right to left: sand, sandy loam, humous soil and clay.

Compute the rate of percolation in each soil.

Distance of percolation in inches-----

Time required for percolation-----

Rate of percolation per hour-----

Questions—1. What are the conditions that make the difference in time for the percolation of water through the different soils? 2. Which soil would take in the most rainfall? 3. Which soil would possess the most water ten days after a rain? Explain.

NOTE.—Read carefully Study Number Nine-A before taking up Study Number Nine.

*Study Number Nine A.

The Absorbent Power of Soils.

Apparatus—That used in Study Number Nine.

Materials—Those prepared in Study Number Nine and water leached from barnyard manure.

Procedure—In case this experiment is to be performed in connection with Study Number Nine use the water leached from barnyard manure to pour in on the top of the soils. Allow about a tablespoonful of water to drop through each soil. Compare the color of this water with that poured in at the top. Contrast the water that has run through each type of soil with each other sample.

Questions—1. What was the color of the water coming through each type of soil when compared with the original? 2. Which soil absorbed the most organic matter? 3. What can you say of the soil as a filter? 4. Can we safely count upon all underground water being free of organic matter?

Study Number Ten.

Soil Moisture at Various Depths.

Apparatus—Five soil pans, soil auger, balance and weights, five porcelain crucibles, drying oven.

Materials—To be obtained.

Procedure—Go out into the field and in soil pan No. 1 collect a sample of the top soil, in pan No. 2 soil at the depth of one foot, in pan No. 3 soil at the depth of two feet, in pan No. 4 soil at the depth of three feet, in pan No. 5 soil at the depth of four feet. Close each pan tightly as the soil sample is placed in it.

Take the weight of each soil sample and place in a drying oven for thirty-six hours. Reweigh and reserve for Study Number Thirteen.

Compute the per cent of moisture in each soil sample as follows:

Known weight of soil pan	-----
Weight of pan and soil	-----
Weight of pan and soil dried	-----
Weight of moist soil	-----
Weight of dry soil	-----
Weight of water	-----
Per cent of moisture	-----

Questions—1. Which soil sample had the highest per cent of moisture? 2. How do you account for the conditions found? 3. Would there be any advantage in getting crops to root deep?

*Study Number Eleven.

The Rate of Evaporation in Soils.

Apparatus—Balance.

Materials—Equally moist samples of clay, sand, loam, and humous soil.

Procedure—Set up the balance, fill the pans of the balance, one with moist clay and one with moist sand. Put the pans in exact balance and place the apparatus in

a dry place. (Fig. No. 11.) Note the way in which the balance swings as the soils dry. Continue as above until you have checked every combination possible with the four soils.

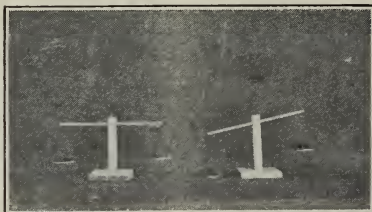


Fig. No. 11. Illustrating study number eleven.

Questions—1. What conditions did you find in the study above? 2. How do you account for them?

Study Number Twelve.

Hygroscopic Water.

Apparatus—Test tube, holder for same, Bunsen burner, small square of window glass.

Materials—Sample of dry road dust.

Procedure—Fill a test tube one-third full of dry road dust. Slowly heat it over the Bunsen flame. Hold the square of glass a little above the mouth of the test tube. Watch for moisture that may gather upon the sides of the test tube and the glass plate.

Questions—1. Did you succeed in driving moisture from the dry dust? 2. How was this moisture held in the dust? 3. Is this moisture of benefit to the plant?

Study Number Thirteen.

The Per Cent of Organic Matter in Soils.

Apparatus—Scales and weights, five porcelain crucibles, Bunsen burner.

Materials—Soil samples reserved from Study Number Ten.

Procedure—Get the soil samples reserved in Study Number Ten. Heat each soil sample to a dull red heat for one hour. When cool reweigh.

Compute the per cent of organic matter in each sample.

Weight of crucible	-----
Weight of crucible and dry soil	-----
Weight of crucible and burned soil	-----
Weight of dry soil	-----
Weight of burned soil	-----
Weight of organic matter	-----
Per cent of organic matter	-----

The remaining material is mineral matter. Record the per cent of mineral matter in each case.

Questions—1. Which soil possessed the most organic matter? 2. What was the color of the soil possessing the most organic matter compared with the others? 3. What was the color of all of them when you finished burning them?

Study Number Fourteen.

The Per Cent of Air in Soils.

Apparatus—Four water glasses, 2 graduate measures.

Materials—Dry samples of clay, loam, sand, humous soil.

Procedure—In each of the water glasses put a twenty-five c.c. sample of soil, in one sand, in one loam, in one clay and in one humous soil. In measuring the soil jar the graduate with the hand to pack the soil firmly. In each glass pour water slowly from a second graduate tube until it comes to the level of the top of the soil. Note carefully the number of c.c. of water taken for each soil. The water occupies the air space in the soil, giving you the air space in c.c.

Compute the per cent of air space for each soil type.

Volume of soil -----

Volume of water -----

Volume of air -----

Per cent of air space -----

Determine the air space in above types of soils secured under natural field conditions.

Questions—1. Is air in the soil necessary for plant growth? Explain. 2. Which soil contained the bigger per cent of air space? 3. Why is too much air space detrimental to plant growth? Too little?

*Study Number Fifteen.

The Soil Types in Relation to Plant Growth.

Apparatus—Six small boxes 8" x 6" x 3" deep.

Materials—Sand, clay, humous soil.

Procedure—Take three of the boxes and fill them to within a half inch of the top: one with sand, one with clay, and one with humous soil. Water each well and place them in a warm, dry, well lighted place. Twenty-four hours later plant two dozen wheat grains in each box. Note the growth of the wheat from day to day. Water each box as needed, giving all the same treatment. (Fig. No. 12.)



Fig. No. 12. Illustrating study number fifteen.

Take the remaining boxes and fill as above, one with a mixture half and half of sand and clay, one with a mixture half and half of clay and humous soil, one with a

mixture half and half of sand and humous soil. Treat these boxes as you treated those above.

Questions—1. In which soils did you secure the best growth? 2. Are the valuable farming soils found under natural conditions pure soils or mixtures? 3. In each case what was the trouble with the pure soil? 4. In each case how did mixtures differ in texture from the pure soils?

Study Number Sixteen.

*Contrasting Methods of Irrigation.

Apparatus—Four boxes 24" x 28" x 8" deep.

Materials—Moist loam soil, wheat seed.

Procedure—Fill the four boxes within one inch of the top. Pack the soil firmly. Plant three rows of seed in each box two inches in depth and three inches apart. Plant them the short dimension of the box. Prepare box No. 1 for sprinkling, No. 2 for flooding, No. 3 for furrowing and No. 4 for subirrigation. (Fig. No. 13.) Irrigate each box as needed until eight to twelve quarts are used upon each. Make note of and contrast plant and root growth in each box.

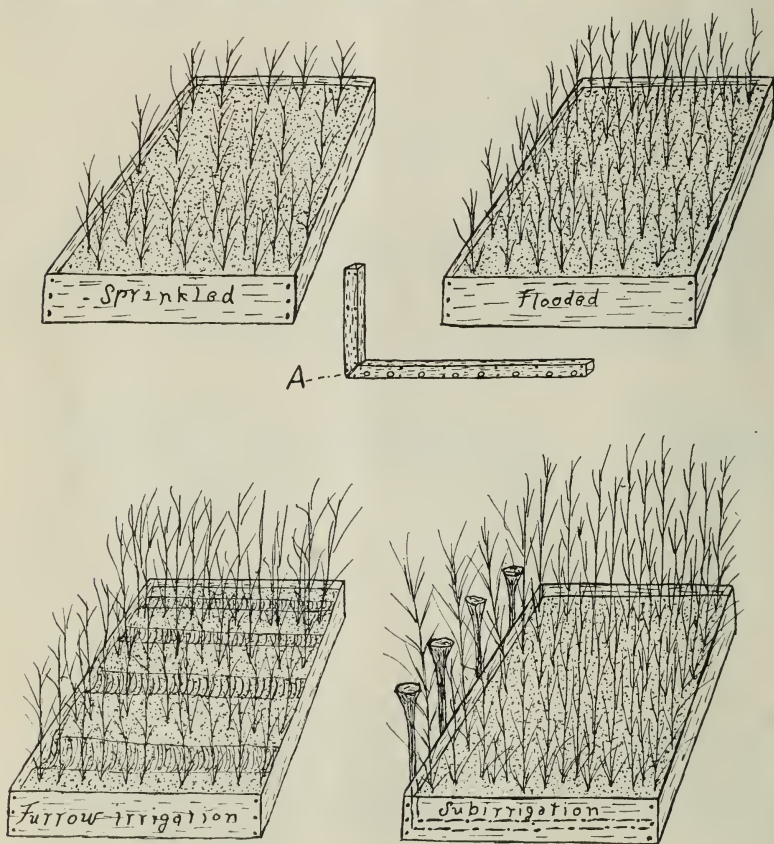


Fig. No. 13. Illustrating study number sixteen.
Perforated lath tube at A used for sub-irrigation.

Questions—1. What conditions did you find under each method of irrigation? 2. Which method proved the best? 3. Would this method be practical under all conditions? Explain.

Study Number Seventeen.*The Effects of Under Drainage.**

Apparatus—Two five pound lard pails, thermometer.

Materials—Good loam soil, fine gravel, wheat seed.

Procedure—Punch a dozen holes in the bottom of one pail, put a half inch layer of gravel in each pail. Fill both to within an inch of the top with good loam soil. Pack the soil firmly in both by jarring the pails down. Plant a half dozen grains of wheat in each pail and water both thoroughly, using the same amount of water for each. In a half hour take the temperature of each and place them in a warm place. Give each can an equal amount of water whenever the plants in the drained can need water. After three weeks' growth dig up the plants in each can and compare them as to foliage and root growth. (Fig. No. 14.)

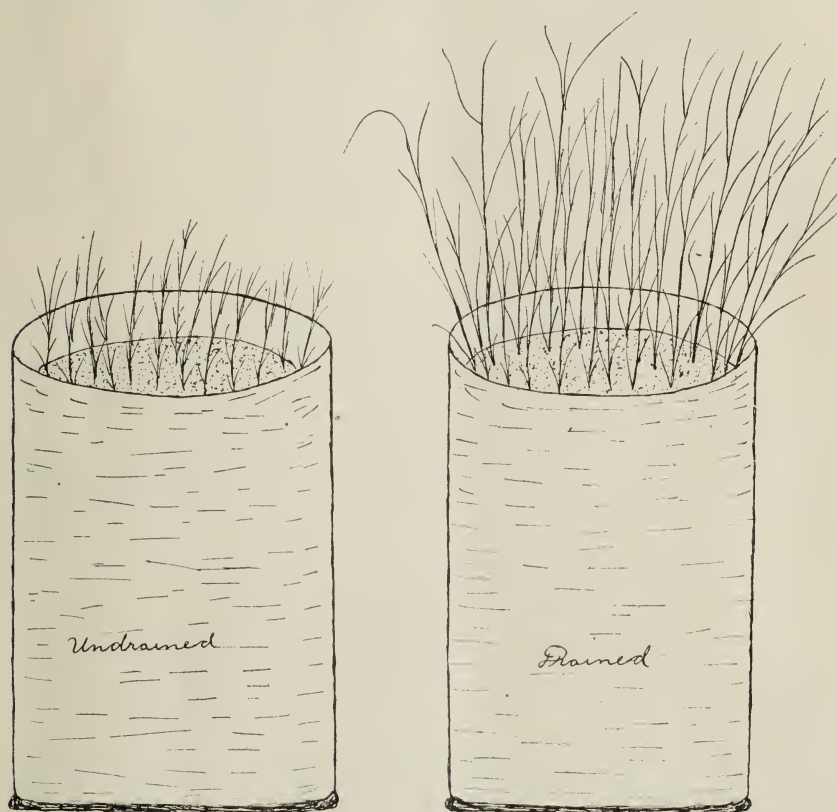


Fig. No. 14. Illustrating study number seventeen.

Questions—1. Which can of soil gave the best growth? 2. What conditions did you find in the poorly drained soil? 3. Why should land be well under-drained?

*Study Number Eighteen.

Illustrating the Action of the Soil Mulch.

Apparatus—Shallow dish.

Materials—Four squares of lump sugar, powdered sugar, diluted solution of red ink.

Procedure—Cover the bottom of the dish an $\frac{1}{8}$ of an inch deep with red ink solution, rub two of the lumps of sugar together to get close contact and then place them one on top of the other with the rubbed surfaces still together, in the red ink. (Fig. No. 15.)

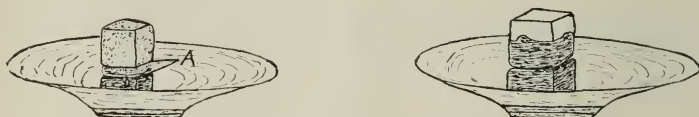


Fig. No. 15. Illustrating study number eighteen.
Layer of powdered sugar at A.

Treat the other two squares in the same way except that you put a $\frac{1}{4}$ inch layer of powdered sugar between the two lumps.

Questions—1. What took place in the tests made above? 2. Would a finely powdered layer of soil over the surface of the ground act as did the powdered sugar? 3. What is the benefit of the soil mulch?

*Study Number Nineteen.

Testing the Action of the Soil Mulch.

Apparatus—Four two quart tin fruit cans, 4 pie pans, scales and weights.

Materials—Garden loam, sawdust or finely chopped straw.

Procedure—Punch a dozen holes in the bottom of each can. Number the cans 1, 2, 3, and 4. Fill cans 1, 2, and 3 within a half inch of the top with soil. Fill can 4 to within three inches of the top. Pack the soil firmly in each by jarring the cans down. Stand each in a pie tin of water until the surface becomes moist. Add water as it is taken up from the pan. As soon as the surface of the soil is moist remove the cans from the water and set them aside until the soil is dry enough to cultivate. Let the soil in can No. 1 remain as it is, cultivate the soil in No. 2 to the depth of two inches, the soil in No. 3 to the depth of three inches. On the soil of No. 4 put a three inch mulch of sawdust or straw. Weigh each can and place them in a dry, warm sunlit window. Weigh each can daily for six days, making a record of each weight. After the last weighing dig into the soil in each can and note its moisture condition.

Questions—1. Which can lost weight the fastest? 2. Which can lost weight the least? 3. How do you account for the conditions found? 4. Is it worth while to keep a soil mulch upon the ground? 5. Would any other sort of mulch be practical under field conditions?

*Study Number Twenty.

Puddling.

Apparatus—Four quart tomato cans.

Materials—Clay, sand, loam and humous soil, wheat seed.

Procedure—Fill each can half full, one with clay, one with loam, one with sand and one with humous soil. Pour water in each and stir until the soil is of the consistency of a thick paste. Plant a half dozen grains of wheat in each can. Set them

aside in the sunlight until the top of the soil in each can is dry, then bring indoors in a lighted room. After several days contrast soil conditions and plant growth in each type of soil.

Questions—1. Which soil puddled the worst? 2. Which soil puddled the least? 3. How do you account for the conditions found in the above study? 4. In which soil did the wheat grow the best? 5. What are the bad effects of puddling?

***Study Number Twenty-one.**

A Field Trip.

Apparatus—Spade, rule, notebook for each student.

Materials—A clear mind, a good pair of eyes.

During the field trip the following points should be noted:

The geological origin of the soils of the region.

Make special note of the following: Evidences of the soil's origin. Different types of soil. Plant life growing on different soil types. Factors of soil formation.

Group the factors of soil formation under the following heads: Atmosphere, water and organic life.

Dig a hole several feet deep and compare as to color, texture and moisture the top soil and the soil at one, two, three and four feet deep.

Question—1. What is the geological origin of the soils in your neighborhood?

NOTE.—Write a report of the field trip telling of all things noted as outlined above.

***Study Number Twenty-two.**

Moisture and Tillage.

Apparatus—Two small boxes, 6" x 8" x 3" deep.

Materials—Good loam soil.

Procedure—Fill each box with dry loam soil. Water each thoroughly and cultivate the soil in one vigorously at once. Set both aside and cultivate the second box of soil after 48 hours. Contrast the texture of the soil in each.

Questions—1. Why should a wet soil not be tilled? 2. What type of soil could be tilled soonest after irrigation. (Study Number Twenty.)

Study Number Twenty-three.

The Water Holding Capacity of Soils.

Apparatus—Scales and weights, 4 funnels, filter paper, cubic centimeter measure.

Materials—Sand, clay, loam and humous soil.

Procedure—Place the funnels in a rack. In each funnel put a sheet of filter paper. Moisten each piece of filter paper and allow each to drain until water ceases dripping from the funnel. Under each funnel place a dry beaker. In each funnel put 25 c.c. of soil, in one loam, one sand, one clay and in one humous soil. To each add slowly 25 c.c. of water and let them drain until water ceases dripping from the funnels. Measure the number of cubic centimeters of water that dripped from each sample.

Compute as follows:

Volume of soil -----

Volume of water -----

Water holding capacity -----

Questions—1. Which soil held the most water? 2. Which soil held the least water? 3. How do you account for the conditions observed above?

***Study Number Twenty-four.**

Some Conditions Affecting Soil Temperature.

Apparatus—Four small boxes, thermometer.

Materials—Loam, lime or chalk dust.

Procedure—Fill each of the four boxes to within an inch of the top with moist loam. Water one box thoroughly. Over the surface of one sprinkle a thin layer of lime or chalk dust. Place these boxes in the sunlight, three so that they face the south, two of these being the wet soil and the soil with the lime covering, and one facing the north in imitation of a north slope.

Take the temperatures of these soils for two bright sunny days at 8 o'clock, 10, 12, 2 and 4.

- Questions*—1. What temperature conditions did you find in each case above?
2. Which soil absorbs the most heat, light or dark? 3. Why is a damp soil cold?
4. Which slope would warm up earlier in the spring, a south or a north?
-

***Study Number Twenty-five.**

Effects of Lime Upon the Soil.

Apparatus—Pint jar, 2 six ounce bottles, 2 pie tins.

Materials—Clay, lime.

Procedure—(a) Fill the pint jar with water. Put two spoonfuls of fine clay in it and stir thoroughly for three or four minutes. Let the mixture settle for five minutes. Fill the two bottles with water from the jar, taking care not to stir up the sediment collected at the bottom. Into one bottle put a piece of lime the size of a bean and shake the contents well. Shake the other bottle thoroughly. Set the two bottles aside for twenty-four hours, occasionally taking note of any changes that may occur.

(b) Fill the pie tins three-fourths full of fine clay soil. To one add two teaspoonfuls of lime. Add water to both and stir until they are of a thick pasty consistency. Set them aside where they will dry. When dry remove the hardened soil and pulverize some from each pan. Note the effort needed to pulverize each.

- Questions*—1. What changes took place in the bottles prepared in section (a)?
2. What caused this? 3. What conditions did you find in the soils prepared in the pans? 4. What results could be expected from putting lime on a stiff clay soil?
5. Would it be practical to do this always? Explain.
-

Study Number Twenty-six.

Some Principal Ingredients of White and Black Alkali.

Apparatus—Three quart tin cans, 3 pie tins.

Materials—Clay loam, sodium carbonate, sodium chloride, sodium sulphate.

Procedure—Fill the cans to within a half inch of the top with dry finely pulverized clay loam. Label the cans 1, 2, and 3. In a pie tin mix with the soil in can No. 1 fifteen grams of well powdered sodium carbonate (Na_2CO_3) and return to the can. In the same way mix in the soil in can No. 2 eight grams of sodium chloride (NaCl) and eight grams of sodium sulphate (Na_2SO_4). Add enough water to all three cans to saturate the soil. Thoroughly pack the soil in each can and place them in a warm place for a few days. Note results. Can No. 3 serves as a check. Contrast the surface of the soil in the cans with the surface of alkali soils under natural conditions.

- Questions*—1. What comes about as the cans of soil dry? 2. What are the differences in the incrustations in cans 1 and 2? 3. How is alkali brought to the surface?

Study Number Twenty-seven.

The Gypsum Treatment for Black Alkali.

Apparatus—Quart tin can, pie tin.

Materials—Sodium carbonate, calcium sulphate (land plaster).

Procedure—Fill the can to within a half inch of the top with well pulverized clay loam. Mix thoroughly into it 15 grams each of sodium carbonate (Na_2CO_3) and calcium sulphate (CaSO_4). Slowly add water to the soil until it is saturated. Compact the soil thoroughly and place it in a warm place in the laboratory. After several days' drying note conditions.

Questions—1. What conditions do you find here? 2. What has become of the black alkali? (NOTE.—The sodium carbonate reacts chemically with the calcium sulphate, to form insoluble calcium carbonate and sodium sulphate.) 3. Would the gypsum treatment of black alkali land be practical under all conditions?

*Study Number Twenty-eight.

Cropping and Draining White Alkali Soils.

Apparatus—Three boxes 3' x 2' x 1' deep, spade, drain tile.

Materials—White alkali soils, alfalfa, sugar beet, tobacco, barley, wheat and oat seed.

Procedure—Fill the boxes to within three inches of the top with moist alkali soil. Label the boxes 1, 2, and 3. Arrange the drain tile to thoroughly drain box No. 1. In box No. 2 plant a row each of tobacco, sugar beets and alfalfa. In box No. 3 plant a row each of wheat, barley and oats. Flood box No. 1 with three inches of water every day for four days. When the soil is in proper condition for planting, plant a row each of barley, oats and wheat. Irrigate the soil in each box as the plants need and watch their growth for a month. (Fig. No. 16.)

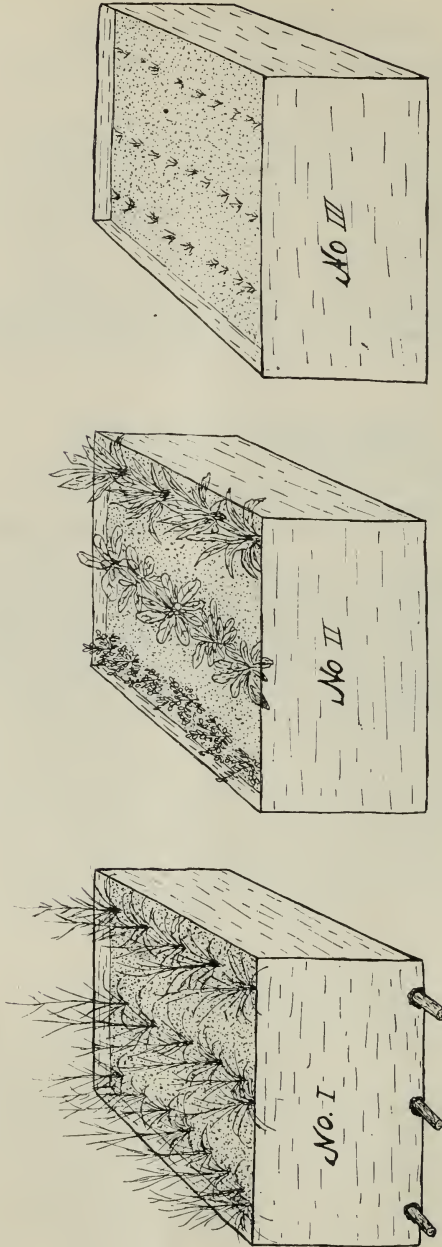


Fig. No. 16. Illustrating study number twenty-eight.

Questions—1. What conditions do you find in each box? 2. How do you explain these conditions? 3. What sort of crops would you call alfalfa, tobacco and sugar beets?

Study Number Twenty-nine.

Tests for Alkali Soils and Acid Soils.

Apparatus—Three pie tins, red and blue litmus paper.

Materials—To be obtained.

Procedure—Collect soil samples from alkali soils, and from boggy soil and poorly drained heavy clay soil. Put a handful of each in separate pans. Put in each soil sample small strips of red and blue litmus paper. Moisten each with distilled water and press the soils down firmly about the paper. Allow them to stand an hour or two. Remove the litmus papers and wash them thoroughly with distilled water and dry them. When dry examine them and compare the color of each with the original litmus paper. "Black alkali" will turn the red litmus to blue. Acid soils will turn blue to red.

Questions—1. What results did you get in the above study? 2. What are the physical appearances of an acid soil? Of an alkali soil? 3. Judging from past studies, how could each be corrected?

*Study Number Thirty.

The Composition of Loam.

NOTE.—Section (a) of this study can be taken up without the microscope and is a complete and interesting study in itself.

Apparatus—Three pint fruit jars, microscope.

Materials—Loam.

Procedure—(a) Fill a fruit jar two-thirds full of water and in it put three tablespoonfuls of loam. Screw on the top and shake the jar vigorously for two minutes. Set it aside for twenty-four hours and during this time shake the jar occasionally.

After twenty-four hours give the jar a vigorous shaking for five minutes. Set the jar on a level surface. Allow to settle one minute. Carefully pour the roily water into another jar. Let this settle one hour. Pour off the roily water and evaporate in a drying oven. (Fig. No. 17.)



Fig. No. 17. Illustrating section (A) of study number thirty.

When the three soil settlings are dry examine the separates. The first settling is sand, the second silt, the third clay. (Each will contain some organic matter.) Examine each to note differences in texture. Which ones would puddle easily? Would pure sand or pure clay make a good soil?

(b) Examine the sand under the microscope with a magnification of fifty diameters.

Mix a little silt with water and examine a drop under the microscope, magnifying 100 diameters. Do the same with clay, magnifying 500 diameters. Note what the soil particles are in each soil type. Make drawings of each type as it appears under the microscope. In each case find black particles of humus and draw them separately.

Look for flocculated particles of clay (a number of particles united to form a compound particle). The keeping of the soil in a good condition is largely a matter of keeping the soil particles well flocculated.

*Study Number Thirty-one.

The Effects of Plowed-Under Manures Upon Capillarity.

Apparatus—Three student lamp chimneys, 3 water glasses, rack, cheesecloth, rubber bands.

Materials—Dry loam, straw, well rotted manure, hard lumpy clay.

Procedure—Fasten a square of cheesecloth over the small end of each lamp chimney with a rubber band. Fill each two-thirds full of dry loam. Jar the lamp chimneys with the hand to pack the soil. Label them 1, 2 and 3. On the soil in No. 1 put an inch layer of finely chopped straw, in No. 2 an inch layer of well rotted manure and in No. 3 an inch layer of hard clay lumps the size of a pea. Put in each chimney two inches more of dry loam. Put the lamp chimneys in the rack with each dipping into a glass of water. Note the rise of water by capillarity. (Fig. No. 18.)

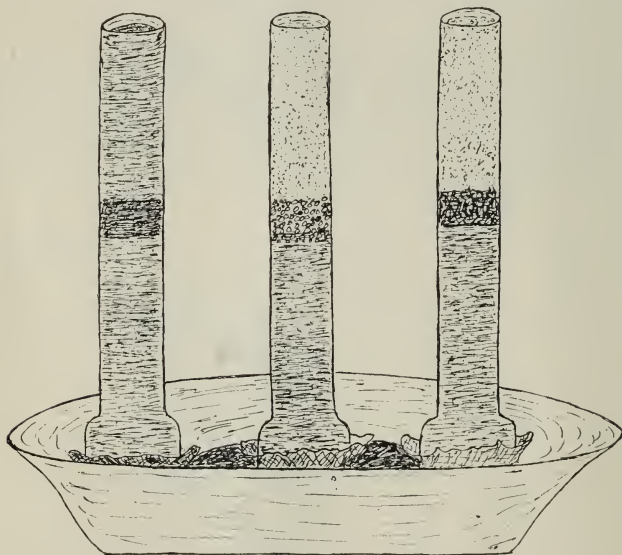


Fig. No. 18. Illustrating study number thirty-one.

Questions—1. Through which does the water pass the fastest—the straw, clay lumps or well rotted manure? 2. If the top soil were the furrow slice and straw, manure and clods represented material plowed under, in which would newly planted crops do the best? Explain. 3. When should coarse strawy manure be plowed under? 4. When should hard dry soil be plowed? 5. Is it safe to plow under well rotted manure at any time? Explain.

*Study Number Thirty-two.

Farm Fertilizers.

Apparatus—Four boxes 8" x 6" x 3" deep, meat grinder or a chopping knife.

Materials—Sandy soil, green alfalfa or clover, green wheat or rye, rain water, well rotted barnyard manure.

Procedure—Fill the boxes to within an inch of the top with moist sandy soil. Label them 1, 2, 3, and 4. Treat soil in box No. 1 as follows: Over the top of the soil spread a half inch layer of green clover or alfalfa pulp. (To make this pulp secure some succulent clover or alfalfa, roots and all, and wash the dirt from them and run them through a meat grinder or chop them to a pulp with a chopping knife. Take special care to keep the plant juice with the pulp.) Mix the pulp thoroughly with the soil. Treat the soil in box No. 2 as above with a pulp made from green rye or wheat. Treat box No. 3 with a half inch layer of well pulverized, moist, fresh barnyard manure. Leave box No. 4 to serve as a check. Put all of the boxes in warm well lighted place and water each with distilled or rain water. Never add more water than the soil can take up, that is, do not add water until it drips from the box. After forty-eight hours plant three dozen grains of wheat in each box. Water each box as needed and watch growth for a month or six weeks. (Fig. No. 19.)

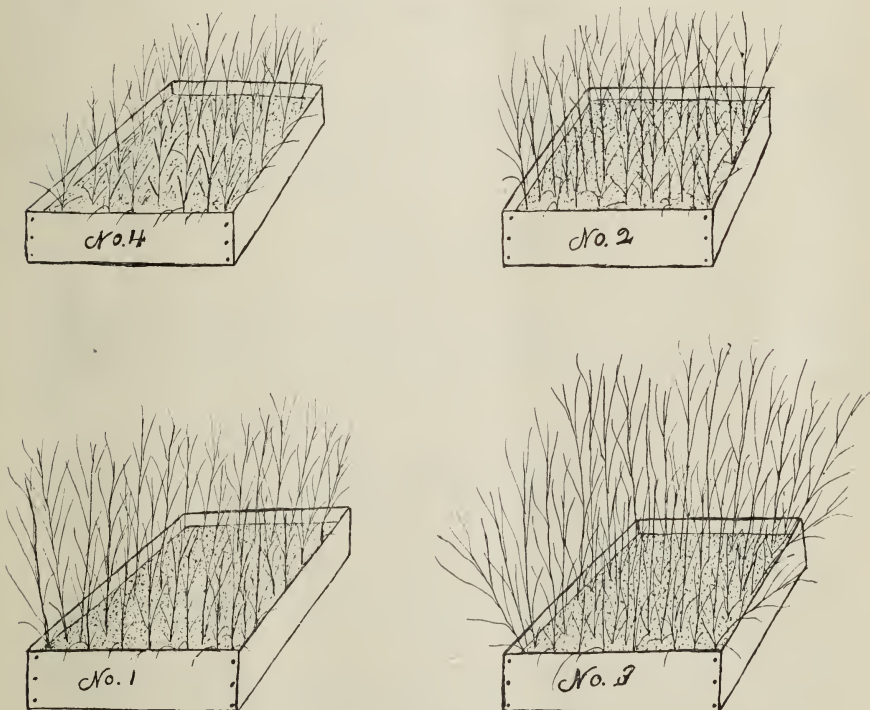


Fig. No. 19. Illustrating study number thirty-two.

Questions—1. What conditions of growth did you observe in each box? 2. If you are going to plow under green crops, what sort are best? 3. Would other legumes, as cowpeas or soy-beans, be as good as alfalfa or clover? 4. Which would pay best, to plow under a green crop or let the crop mature, feed it to animals, and return the manure from the crop to the land?

Problem—The average farm animal returns about 70 per cent of its food as manure. A ton of alfalfa hay would make how much barnyard manure?

PLANT STUDIES.

Study Number One.

The Elements Used as Plant Food.

The elements used as plant food are carbon, calcium, aluminum, iron, phosphorus, potassium, magnesium, sulphur, sodium, silicon, hydrogen, oxygen, nitrogen and chlorine.

Procedure—From the laboratory reference books look up and record the properties of the elements given above.

Questions—What is an element? What is a compound? In what form do most elements exist?

Tell in what form or forms the above elements exist and of their abundance.

NOTE.—After you have finished the following studies to and including Study Number Forty-four, return to this experiment and with the aid of your above notes tell the source of each element above as plant food and how it is obtained and appropriated by the plant.

Study Number Two.

The Mineral Matter in Plants.

Apparatus—Three porcelain crucibles, Bunsen burner.

Materials—Dry plant, piece of meat, loam soil.

Procedure—Take a dry plant, place it in a crucible and burn it as completely as possible. Is there anything left? What do you call it? It is composed of the mineral matter of the plant body. The process of burning is what sort of a chemical change? What becomes of the elements composing the major portion of the plant body?

Treat a piece of meat as you did the dry plant. Can you burn it entirely away?

Put some loam in a crucible. Treat it as you did the plant. Take note of results during the burning.

Questions—1. What do you suppose is the use of the mineral matter in the plant body? The animal body? 2. Where do plants get their mineral matter? 3. Where do animals get theirs? 4. What becomes of the plant and animal body after death?

Study Number Three.

The Water in Plants.

Apparatus—Scales, weights, drying oven, knife.

Materials—Young green plant, apple, potato, piece of meat.

Procedure—Weigh a green young plant, a peeled apple or potato and a piece of meat. Put all in the drying oven for twelve hours. Reweigh. Record the loss of weight in each case.

Questions—1. What was the loss of weight in each case above? 2. What caused the decrease of weight? 3. What uses do plants and animals make of water?

Problem—In each case compute the percentage of water loss.

Original weight -----
 Weight after drying -----
 Per cent of loss -----

Study Number Four.

Carbohydrates (Starch).

Apparatus—Test tube, mortar and pestle, Bunsen burner, medicine dropper.

Materials—Starch, iodine.

Procedure—Grind the starch with a mortar and pestle. In the bottom of a test tube place a quantity of starch the size of a large pea. To this add a half test tube of water. Heat slowly until the water is quite warm to the touch. Add a few drops of solution of iodine.

Question—1. What change do you note? A black color indicates an excess of starch.

Starch is a compound of hydrogen, carbon and oxygen. The above procedure is the usual test for starch.

Study Number Five.

Carbohydrates (Grape Sugar).

Apparatus—Test tube, Bunsen burner.

Materials—Glucose, Fehling's solution.

Procedure—Put a ball of glucose the size of a bean in a test tube one-fourth full of water. Shake until the glucose is dissolved. Add two-thirds the amount of Fehling's solution and boil.

Question—1. What change in color takes place in the solution?

Should grape sugar be present in any substance treated as above, the contents of the tube will turn either a yellowish brick red or deep orange color.

The above is the usual test given for grape sugar. It is a compound of the elements carbon, hydrogen and oxygen.

Study Number Six.

Fats and Oils.

Apparatus—Watch glass, mortar and pestle.

Materials—English walnut, almond, flax seed, ether.

Procedure—Take a small piece of animal fat and crush it on a piece of white glazed paper. Hold the paper up to the light and note results. Do the same with a kernel of an English walnut; of an almond.

Grind up with mortar and pestle some flax seed, place a fourth of a teaspoonful in a watch glass, add ether and allow it to stand until it evaporates. Note what is left. Ether dissolves and separates oils from substances and in evaporating leaves the oil on the container. The above are usual methods for testing for fats and oils.

Fats and oils are composed of carbon, hydrogen and oxygen.

Study Number Seven.

Proteids.

Apparatus—Test tubes, mortar and pestle.

Materials—Egg, nitric acid, ammonia, wheat.

Procedure—Place a little white of an egg (raw) in a test tube. To this add a little nitric acid. Note any change of color. Rinse the material in the test tube with water and pour in a little ammonia. Note any change of color. Grind up a few grains of wheat and test as above. Do the same with corn. Note results. A greenish yellow, and a lemon yellow or a deep orange color indicates proteids.

Drop a little of the raw white of an egg in a test tube of boiling water. Note what takes place. A coagulation indicates a proteid called albumen.

The above are the usual tests for proteids. Proteids are composed of carbon, hydrogen, nitrogen and oxygen.

Study Number Eight.

A Summary of Previous Studies.

Apparatus—Test tubes, mortar and pestle, Bunsen burner, porcelain crucibles, scales and weights.

Materials—Potato, wheat, bread, meat, iodine, ammonia, nitric acid, ether, Fehling's solution.

Procedure—Test each of the following materials for starch, fats and oils, grape sugar, mineral matter and water :

	Bread	Potato	Wheat	Meat
Proteids.....				
Fats and oils.....				
Starch.....				
Grape sugar.....				
Minerals.....				
Water.....				

*Study Number Nine.

The Flower.

Apparatus—Set of dissecting tools, microscope, slides, cover glasses.

Materials—Several flowers.

Procedure—(a) Take one of the flowers. Note the bright conspicuous part of the flower. This is named the corolla. Its separate leaves are called petals. Note the number of petals.

(b) Pull off the petals of the corolla. Note the little green bowl-like base (calyx). Note the little green leaves attached to calyx (sepals). Note the little spike-like growth extending up from the center of the calyx (pistil). Note the little thread-like growths growing up from the inner sides of the calyx or from the pistil (stamens).

(c) Note three distinct parts of the pistil. Draw and label each part. Make a drawing of the stamen and label each part.

Take a second flower, make a longitudinal section of it and draw the flower as seen thus, labeling all parts. (Fig. No. 20.)

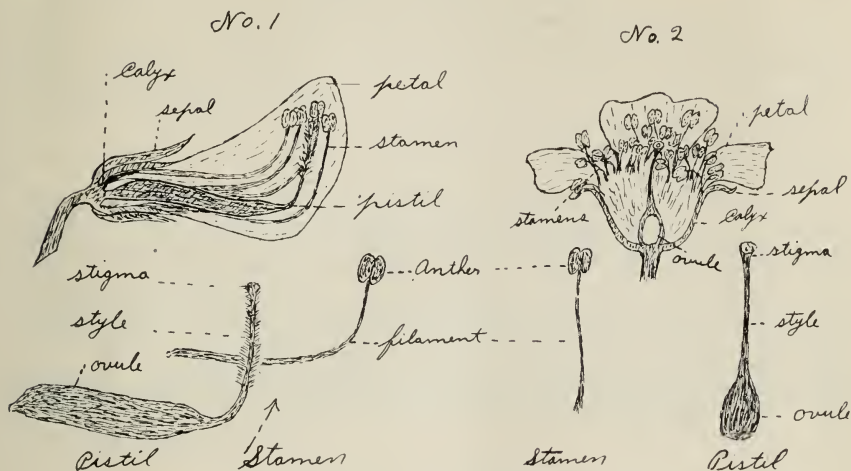


Fig. No. 20. Illustrating study number nine.
1.—The flower of the sweat pea.
2.—The flower of the cherry.

(d) Secure a high power microscope and make and examine a slide of pollen grains. Draw them as seen.

Make a longitudinal slide of the calyx and examine the same. Draw and label parts as seen.

Put a few pollen grains in a drop of growing solution on a microscope slide. Keep the slide in a moist air chamber. Examine daily, taking note of the growth of the pollen grain.

(e) Collect a number of different kinds of flowers and identify the parts of the flower in each. Make a drawing of a longitudinal section of each flower, labeling parts.

Questions—1. What are the functions of the following: corolla, calyx, style, ovule, stigma, filament, anther and pollen? 2. What does the pistil consist of? The stamen? 3. How does the pollen grain fertilize the ovule? Illustrate by drawing.

Study Number Ten.

The Types of Fruits.

Apparatus—Knife.

Materials—Fruit of the following plants: wheat, oats, walnut, maple, elm, bean, pea, alfalfa, plum, peach, melon, squash, blackberry, currant and orange.

Procedure—Classify the above fruits (first) as dry and fleshy, (second) the fleshy fruits as drupe, accessory, aggregate and berry, (third) the dry fruits as dehiscent and indehiscent.

Make a drawing of the cross section of the following and show the parts that developed from the endocarp, exocarp and the ovule.

It is the function of the flower to produce the fruit. Tell briefly of the economic importance of plant fruits.

*Study Number Eleven.

The Structure of the Seed.

Apparatus—Set of dissecting tools, dissecting microscope, two plates, blotting paper.

Materials—Seed of the corn and of the bean that have been soaked twenty-four hours, dry seeds of the corn and the bean.

Procedure—Making a drawing of the bean seed showing the radicle ridge, micropyle, hilum and raphe.

Split a soaked bean the long way by inserting the point of the knife just below the raphe and running it around the bean to the side opposite the hilum. Make a drawing indicating the seed coat, the cotyledons, the radicle, the hypocotyl, the plumule.

Cut off one-fourth inch of the pointed end of a soaked grain of corn. Make a drawing of the cross section thus obtained, indicating the seed coat, cotyledon, endosperm and radicle.

Split a grain of corn in halves the long way. Make a drawing of the cross section thus obtained showing seed coat, radicle, plumule, hypocotyl, cotyledon and endosperm. (Fig. No. 21.)

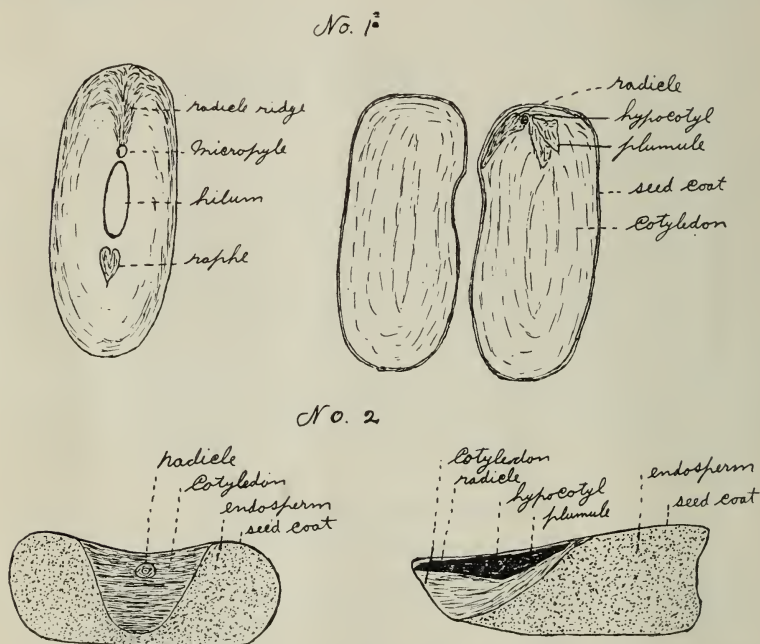


Fig. No. 21. Illustrating study number eleven.

No. 1.—The parts of the bean seed.

No. 2.—The parts of the corn seed.

Plant a half dozen dry bean seeds and a half dozen dry corn seeds in damp sand. Place them in a warm place until they germinate. Note several times each day the difference in plant structure and processes of germination as each germinating seed presents the young plants to view. Illustrate by drawings.

Plant in damp sand a few of each of the following seeds and class them either with the class represented by the bean seed or by the corn seed:

Wheat, pumpkin, squash, radish, cabbage, oats, rye, turnip, alfalfa, bluegrass, clover and onion.

Questions—1. Are we justified in speaking of the seed as an embryo plant? Explain. 2. What is the function of the following: micropyle, hilum, seed coat, radicle, hypocotyl, plumule? 3. Plants bearing seeds similar to the bean are given what name or classification? Similar to the corn seed? 4. In what class do our important food grains come?

*Study Number Twelve.

The First Step in Seed Germination.

Apparatus—Glass tumbler or beaker, Bunsen burner, ring-stand, 250 c.c. flask and cork to fit flask.

Materials—Water and half dozen Windsor beans.

Procedure—Fill the 250 c.c. flask half full of water and heat over the Bunsen burner until it boils. Note what takes place as the water begins to get warm. When the water reaches the boiling point cork the flask and set it aside. Allow the water to cool until quite warm and into it drop the Windsor beans. Note what takes place. (Fig. No. 22.)

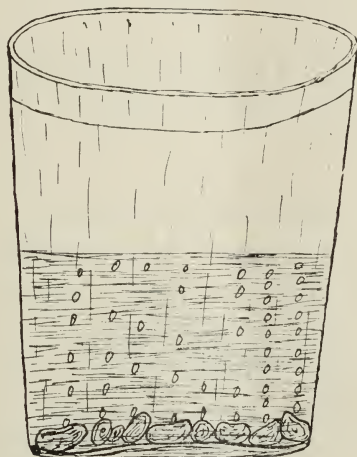


Fig. No. 22. Illustrating study number twelve.

Questions—1. What formed the tiny bubbles seen as the water got warm? 2. What caused them to rise? 3. How did this air come to be in the water? 4. What class of plants make use of the air in water? 5. From what part of the seed did bubbles rise? 6. What caused the bubbles to form? 7. How does the water first enter the germinating seed?

*Study Number Thirteen.

The Function of the Cotyledon and Endosperm.

Apparatus—Two small boxes, knife.

Materials—Sand, bean seed and corn seed that has been soaked twenty-four hours.

Procedure—Plant three rows of beans in a box of sand. As the beans break through the soil pinch off both cotyledons from one row of plants, one cotyledon from each plant in the second row and let the plants in row three grow normally. Water the plants as needed. (Fig. No. 23.)



Fig. No. 23. Illustrating study number thirteen.

Plant in the second box a row of plump corn seed and a row of seed soaked for twenty-four hours from which the endosperm has been cut. Note how each grows.

Questions—1. In each case above, which plants made the best growth? 2. What is the function of the cotyledon? Of the endosperm?

*Study Number Fourteen.

The Processes of Seed Germination.

Apparatus—Pie tin, two glass plates 4" x 4", blotting paper, two heavy rubber bands.

Materials—Water, half dozen grains of wheat, half dozen seeds of radish.

Procedure—Clean both plates of glass thoroughly. On one place the radish seed, scarred side down, in a row near the top. Over these place a half dozen thicknesses of blotting paper 4" x 4" square. On the blotting paper place the grains of wheat in a row near the top grooved side up and over these place the second glass plate. Place rubber bands tightly around the pack, one near the top and one near the bottom. (Fig. No. 24.)

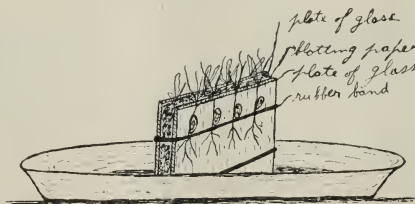


Fig. No. 24. Illustrating study number fourteen.

Fill the pie tin part full of water and set the seed pack on end in the water with seeds at the top. Put in a warm, well lighted place. Renew the water supply in

the pan each day and carefully watch the root growth for ten days or two weeks. (Fig. No. 24a.)

Questions—1. What part of the young plant broke the seed coat first? 2. Is there any tendency of the roots to grow into the blotter? What causes this?

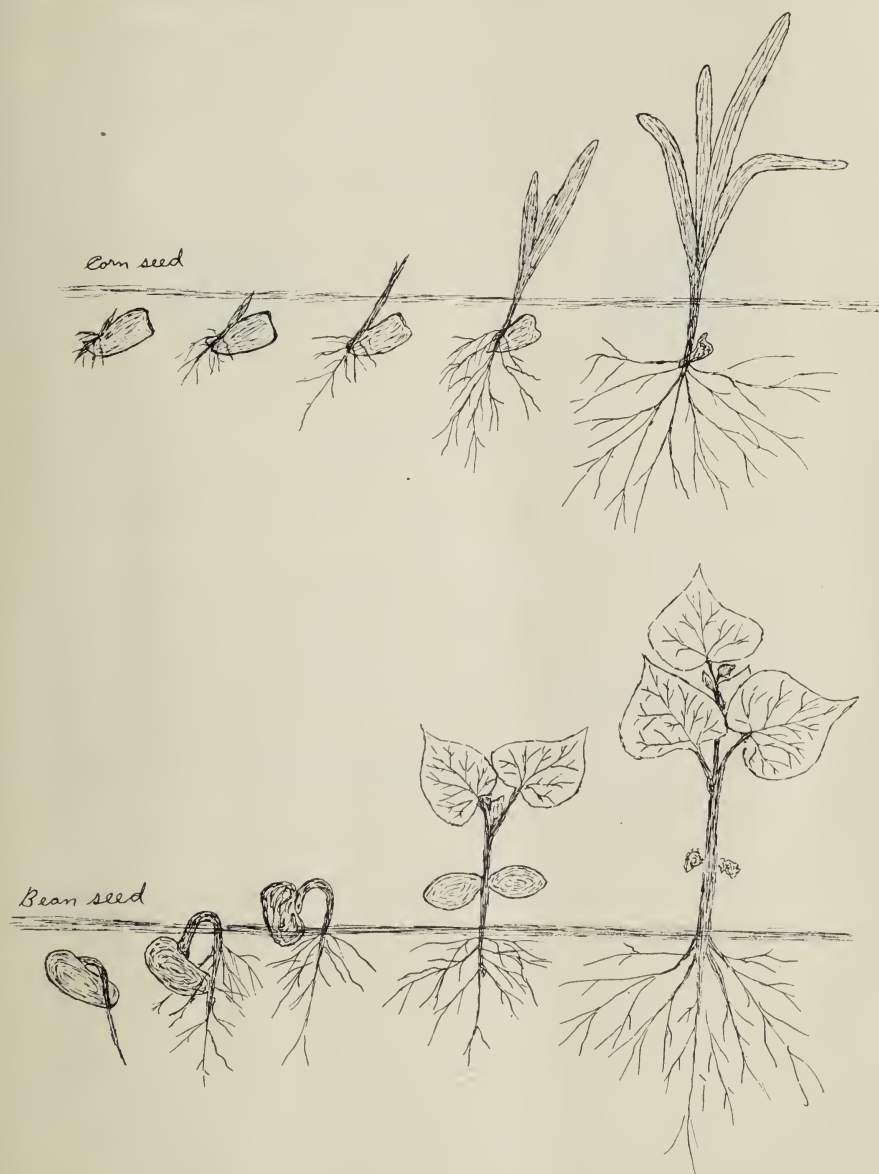


Fig. No. 24a. Illustrating study number fourteen.
Five stages in seed germination.

3. What was the color of the seed leaf when it broke the seed coat? 4. How long was it in changing color? 5. What has this color to do with plant growth? 6. What becomes of the seed as the plant grows? 7. When is a young plant capable of taking care of itself?

Study Number Fifteen.

Preparation of Oxygen.

Apparatus—Ring-stand, several test tubes, rubber tubing, four wide-mouthed bottles, four glass plates, pneumatic trough, Florence flask.

Materials—Potassium chlorate, manganese dioxide, taper or splinters of wood.

Procedure—Set up the apparatus for preparing oxygen (Fig. No. 7). Mix thoroughly 8 grams of potassium chlorate and 6 grams of manganese dioxide. Place it in a Florence flask for heating, which is connected with a rubber tube for the collection of the gas over water. Heat the test tube carefully in a way to secure a gentle evolution of the gas. Collect several bottles of the gas and test each with a glowing splinter. Note what takes place.

Questions—1. What took place when the glowing splinter was put in the oxygen gas? 2. Could you justly call the phenomenon seen above a reliable test for an excessive presence of oxygen?

Study Number Sixteen.

Preparation and Properties of Carbon Dioxide.

Apparatus—Florence flask, stopper, delivery tube, thistle tube, three wide-mouthed bottles, rubber tube, pneumatic trough.

Materials—Marble chips, lime water, hydrochloric acid, splinter, candle.

Procedure—Put a few marble chips into the Florence flask equipped with two-holed stopper, thistle tube and delivery tube. (Fig. No. 7.)

Pour in enough water to cover the marble chips and then add an equal amount of hydrochloric acid. Collect three bottles of the carbon dioxide gas over water.

Invert a bottle of the gas over a lighted candle. Thrust a glowing splinter into one bottle. Pour a little lime water into the third bottle. Take careful note of the results in each case.

Questions—1. What results did you get in the test with lime water? With the lighted candle? 2. Are you justified in considering the above phenomenon a reliable test for carbon dioxide gas?

Study Number Seventeen.*What Do Germinating Seeds Take From the Air and Return?**

Apparatus—Two pint bottles.

Materials—Bean seed, splinter.

Procedure—Soak six dozen bean seeds for twenty-four hours. Put them in one of the pint bottles and close it airtight. Also close the other bottle airtight. Leave the bottles thus for forty-eight hours. Carefully open each bottle and in it thrust a burning splinter at the time of opening. Close immediately. Open again and into each pour a little lime water. (Fig. No. 25.)

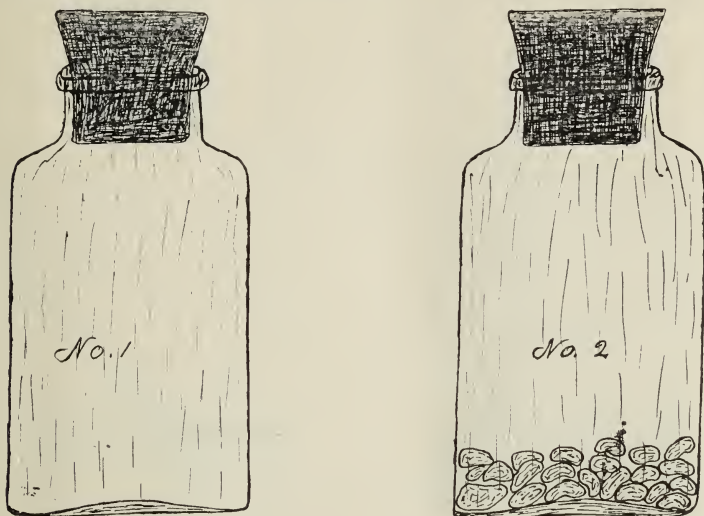


Fig. No. 25. Illustrating study number seventeen.
No. 1.—Empty bottle serving as a check.
No. 2.—Bottle with germinating seeds.

Questions—1. What happened to the burning splinter in each case? 2. How do you account for the results obtained? 3. What did the seeds take from the air? 4. What use did the seeds make of the oxygen? From where did the excess of carbon dioxide come? Explain.

Study Number Eighteen.*The Need of Oxygen for Germination.**

Apparatus—Two pint bottles, rubber stopper to fit bottles, and clean sand.

Materials—Water and six dozen grains of wheat.

Procedure—Fill each bottle an inch in depth with very moist sand packed quite firmly. On the sand in each bottle scatter three dozen grains of wheat. (Fig. No. 26.) Cork one bottle tightly and leave the other open. Place both bottles in a warm place. Note results from day to day. After ten days or two weeks test the corked bottle with lime water.

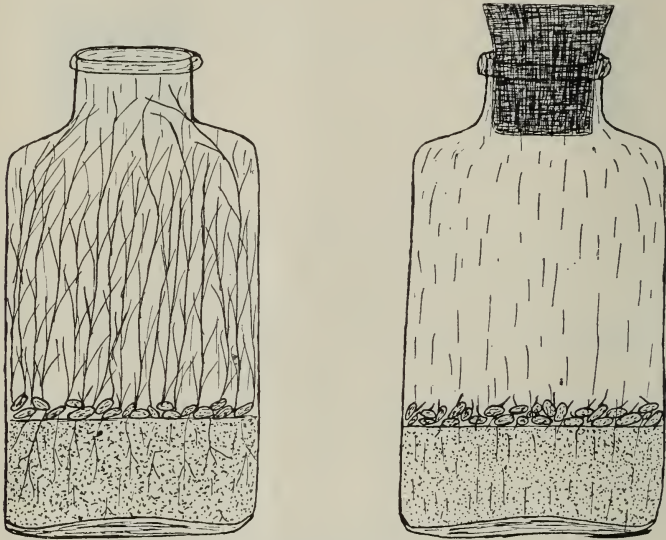


Fig. No. 26. Illustrating study number eighteen.

Questions—1. What difference in growth do you find in each bottle? 2. What is the cause of this difference. 3. What need does this show for seed germination? Where do the seeds covered in soil get oxygen?

*Study Number Nineteen.

The Root Hairs.

Apparatus—Microscope or hand lens.

Materials—Seeds that have been germinated between blotters; young seedling.

Procedure—(a) Take a newly germinated seed possessing the seed leaves fully exposed and a root one to two inches in length. Note the mold-like growth a short distance back of the tip of the root. Put the root under a lens or microscope and examine this mold-like growth. These are root hairs. Isolate one and examine it under the scope. Draw the single root hair as you see it. Make a complete drawing of the plant showing seed leaves, stem, root and root hairs. (Fig. No. 27.)



Fig. No. 27. Illustrating study number nineteen.
A—Root hairs on a young radish.
B—Root hairs clinging to soil particles

(b) Pull a young seedling that has been growing in clean sand. Note how the sand adheres to the small roots. Draw the young plant and root system as seen. Place one of the smaller roots under the microscope. Make a drawing of the root and soil particles as they appear under the scope.

Questions—1. What is the function of the root hairs? 2. By what process do they perform this function? 3. In section (b) what do you find holding the soil particles to the young roots? 4. Under the scope what do these small soil particles appear to be?

Study Number Twenty.*Osmosis.**

Apparatus—Glass tube.

Materials—Paraffine or candle drip; egg.

Procedure—Chip away the shell of the large end of an egg, taking care not to break the membrane underneath. Expose an area of the membrane thus the size of a dime. Break a small hole through the pointed end of the egg and over this hole seal a short glass tube in an upright position by means of melted paraffine. Now place the egg in the top of a wide mouthed bottle in such a position that the exposed membrane is beneath the surface of the water. (Fig. No. 28.) Leave the egg thus for several hours. Illustrate by drawing.

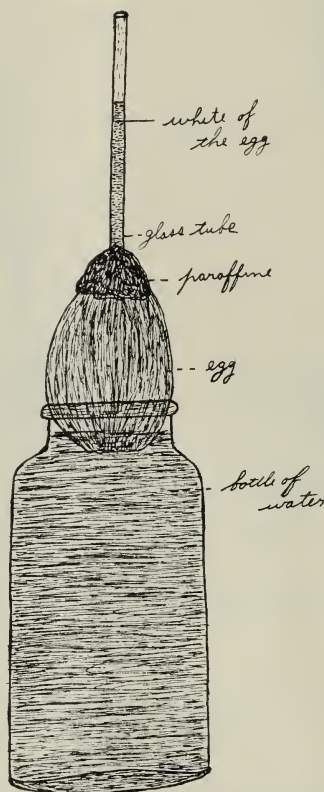


Fig. No. 28. Illustrating study number twenty.

Questions—1. What takes place in the experiment above? 2. Where is osmosis taking place in the plant body? 3. To what height does the white of the egg rise in the glass tube in twenty-four hours? Get the necessary data from the teacher and compute the pressure needed to hold the white of the egg column to height found. What sort of pressure would you call this?

Study Number Twenty-one.*Osmosis.**

Apparatus—Knife, 2 shallow dishes or pie tins.

Materials—Potato, strong salt solution, water.

Procedure—From the potato cut medium thin slices and put three slices in a dish of pure water and three in a dish of salt water. Set them aside for thirty minutes or an hour and then examine them.

Questions—1. What conditions do you find at the end of the half hour? 2. How do you account for the differences? Explain the process of osmosis. 3. Under natural field conditions, where do you find the strongest solution, in the soil or in the young plant roots? 4. Why will young plants not grow in a strongly alkali soil?

Study Number Twenty-two.**Illustrating Root Pressure.**

Apparatus—Glass tubes, ring-stand, rule, rubber tubing.

Materials—Potted geranium.

Procedure—Take the potted geranium and cut the stem off three inches above the soil. On this put a 12" glass tube with a bore the diameter of the plant stem and hold it in place thus with a 2" piece of rubber tubing. Clamp the tube in a vertical position with the ring-stand. Put the plant thus treated where it will have good growing conditions and keep the roots well supplied with water. (Fig. No. 29.)

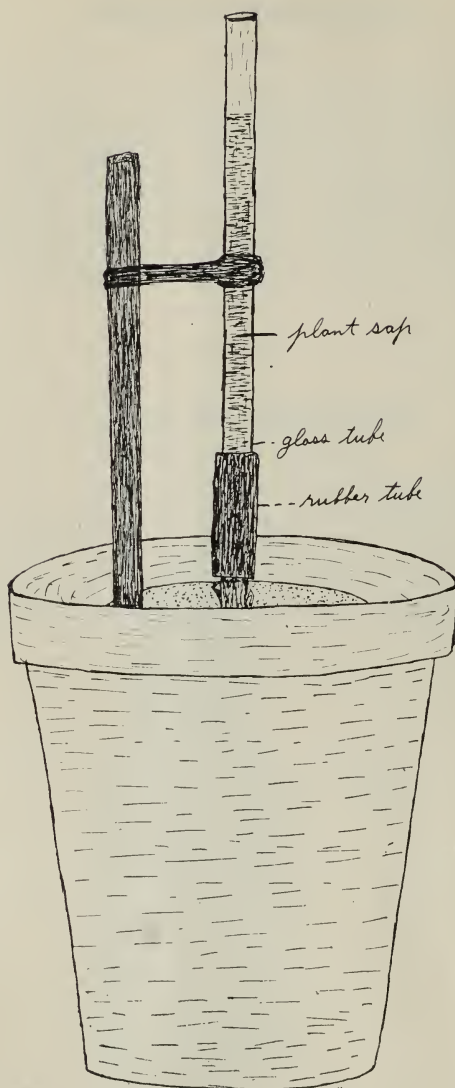


Fig. No. 29. Illustrating study number twenty-two.

Questions—1. What took place in the apparatus arranged above? 2. What was the cause of this? 3. How high was the column of liquid in the glass tube? (Problem—Get from your instructor the necessary data and compute approximately the force required to hold up the column of liquid.) 4. Where was this force exerted and by what?

Study Number Twenty-three.*The Region of Root Growth.**

Apparatus—Pen and ink or indelible pencil, ruler.

Materials—Young plant with vigorous root system that has been grown between damp blotters.

Procedure—Lay the ruler along the side of a root two or three inches long and with a pen mark off eighth inch spaces along the root. (Fig. No. 30.) Treat several roots thus. Keep these plants between moist blotters and observe the roots from day to day. Illustrate by drawing.



Fig. No. 30. Illustrating study number twenty-three.

Questions—1. Are all of the marks on the roots getting further apart? 2. Where do you find a portion of the root that is not marked? 3. What advantage does the increase in length at the place the increase takes place give the root in securing food?

*Study Number Twenty-four.

The Function of the Soil Water.

Apparatus—Two tumblers, 2 rubber bands, 2 squares of mosquito netting 6" x 6".

Materials—Well water, distilled water or rain water and a half dozen grains of wheat.

Procedure—Take the two tumblers and cap each with the mosquito netting in such a manner that it droops down into the tumbler about an inch and one-half in the middle. Hold the netting in this position by placing a rubber band around the top of the glass. Fill one glass with well water and one with distilled water or rain water. Place six seeds upon the netting in each tumbler. See that they are suspended in the water. (Fig. No. 31.) Add water each day to replace that which evaporates. Watch results.

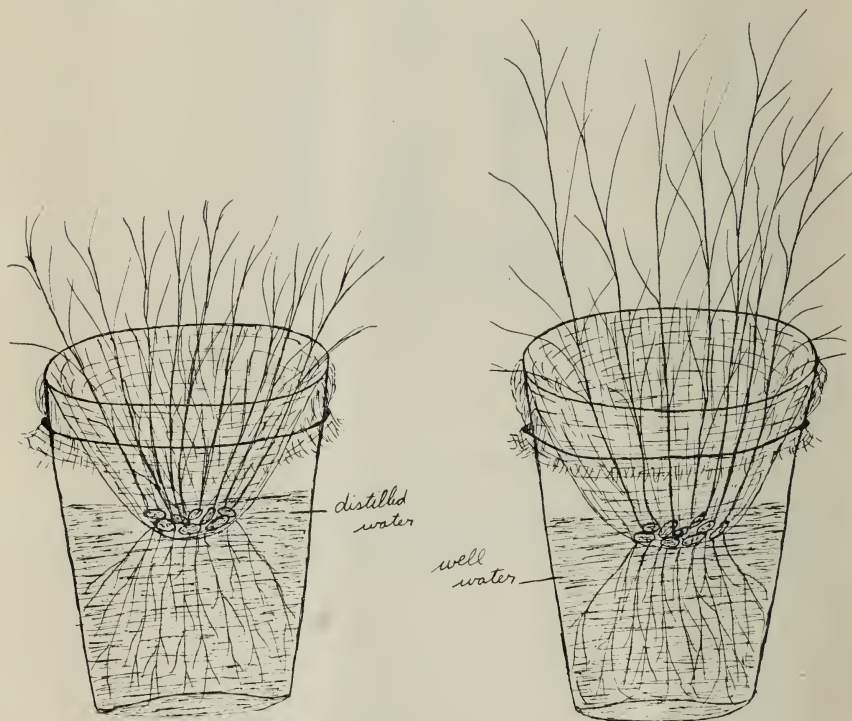


Fig. No. 31. Illustrating study number twenty-four.

Questions—1. How do the seeds in each glass compare in time of germination? How do you account for this? 2. How do the young plants compare in growth after germination? How do you account for this? 3. Of what use is the food stored in the seed? 4. What is the function of the soil water to the plant?

Study Number Twenty-five.*The Plant Takes Food From the Soil.**

Apparatus—Two pint tin cans, 2 iron crucibles or fire shovel, Bunsen burner or stove.

Materials—Distilled water or rain water, wheat seed.

Procedure—Collect two pints of clean sand. Heat it in an iron crucible until all organic matter is burned out. Fill one pint can with the burned out sand and one with natural sand. The cans should have holes in the bottom for drainage. In each can plant a half dozen wheat seeds. Water both cans with distilled water or rain water and put them in a warm place. From this point on, water can No. 1 with distilled water only and can No. 2 with well water. Continue for a month and watch results as the plants grow. (Fig. No. 32.)

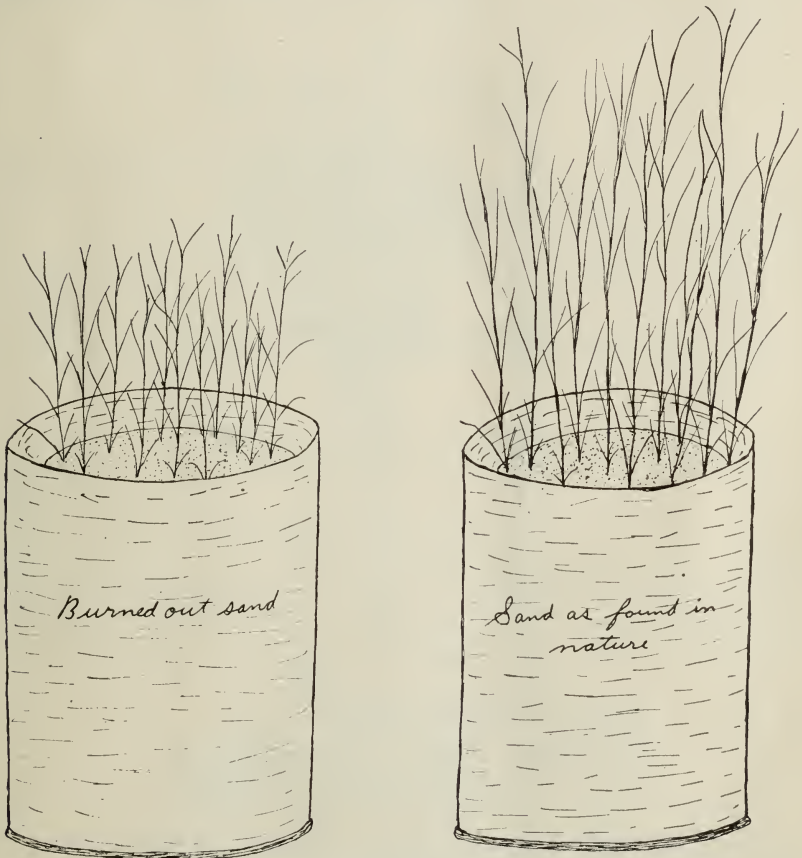


Fig. No. 32. Illustrating study number twenty-five.

Questions—1. What conditions do you find in the two cans? 2. To what is the difference due? 3. What does a natural soil contain? 4. What does all soil water contain?

Study Number Twenty-six.

The Acid Action of Roots.

Apparatus—Glass funnel, ring-stand and funnel support.

Materials—Blue litmus paper, sand, distilled water or rain water and a few grains of wheat.

Procedure—Place the funnel in an upright position with the ring-stand and funnel support. In the funnel place a piece of litmus paper (blue) folded to fit. Fill the funnel with sand washed perfectly clean with distilled water or rain water. Put a few wheat grains next to the litmus paper and keep moist with distilled water or rain water. (Fig. No. 33.) Note what takes place as the seeds grow roots.

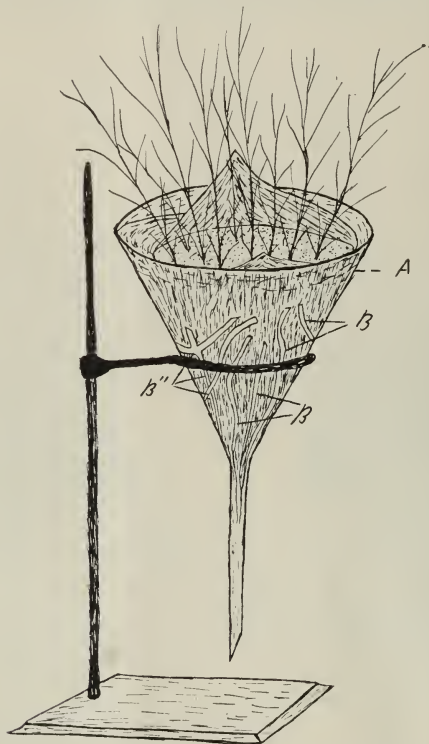


Fig. No. 33. Illustrating study number twenty-six.

A—Glass funnel lined with blue litmus paper.

B, B' & B''—Blue litmus changed to red when the growing roots touched it.

Questions—1. Why was the distilled water or rain water used above? 2. How does the root aid in dissolving solid materials in the soil?

Study Number Twenty-seven.*Legume Plants.**

Apparatus—Spades, notebook.

Materials—To be found.

Procedure—Take a short field trip for the purpose of collecting specimens of the different legume plants growing in the neighborhood. In securing root samples of the plants dig down deep, getting a goodly number of the smaller roots.

Note the growth characteristics of the root systems and of the foliage of the different legumes as they are being dug.

Find the nodules, containing the nitrogen gathering bacteria, upon the roots of the various legumes. Compare them as to size and position. Make a drawing of each type of root with nodules attached.

Questions—1. Where do you find the nodules? 2. In what indirect way do they aid plant growth? 3. What makes the legume crops the most valuable green manure crops? 4. Why is land much improved after five or six years of growing alfalfa?

Study Number Twenty-eight.**The Root Hold of a Plant.**

Apparatus—String, spring balance.

Materials—Vigorous growing young plant in its native soil.

Procedure—Go into the field and find a vigorous young plant. Loop the string firmly around the plant as close to the ground as possible. Hook the spring balance into the opposite end of the loop and slowly pull straight up on the plant. Watch the balance carefully as the pointer runs down and take the reading the instant the plant pulls from the ground.

Questions—1. What force was necessary to pull the plant? 2. What part of this force was due to the weight of the plant? 3. How do you account for the fact that so much force had to be used?

Study Number Twenty-nine.*The Root Seeks the Earth and Darkness.**

Apparatus—Small box.

Materials—Seeds of the bean, young plant, clean sand.

Procedure—Fill the box to within an inch of the top with clean sand. Moisten the sand thoroughly. Plant four beans half the thickness of the seed the hilum down in the sand, four with the hilum turned to the right, four with the hilum turned to the left and four with the hilum facing up. Cover the seeds with moist blotting paper and place the box in a warm part of the room. Keep sand and blotting paper moist. (Fig. No. 34.) Observe from day to day.

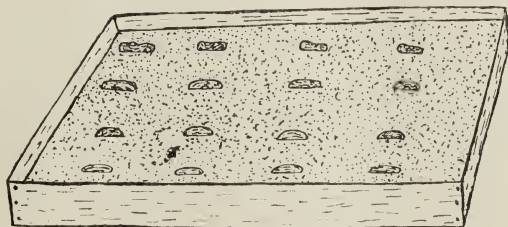


Fig. No. 34. Illustrating study number twenty-nine.

Questions—1. Where does the young root break through the seed coat? 2. Does the position of the seed affect the general direction of root growth? The direction of stem growth? 3. How do you account for the conditions found in the above study?

*Study Number Thirty.

The Root Seeks Moisture and Plant Food.

Apparatus—Small box, wire fly screen.

Materials—Sand, and wheat seed.

Procedure—Knock the bottom out of the box and in its place tack wire fly screen. Fill the box about a third full of moist sand. Plant a dozen wheat seeds in the box and water thoroughly. Place the box in a warm place, propping one end up two or three inches higher than the other. (Fig. No. 35.) Water as needed. Watch root growth.

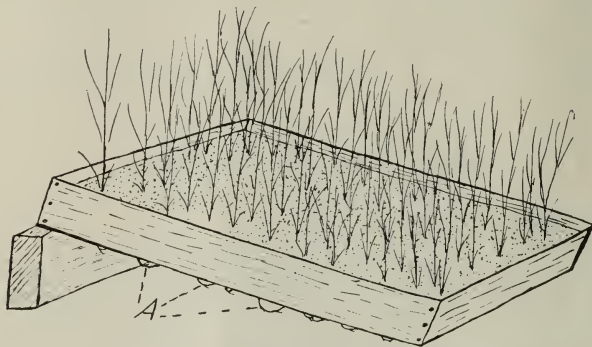


Fig. No. 35. Illustrating study number thirty.
A—Roots growing through screen bottom and then turning back.

Questions—1. Do the roots grow down through the soil? 2. Do they continue to grow on down? 3. Account for the manner of growth that took place.

***Study Number Thirty-one.**

The Stem and Leaves Seek Air and Light.

Apparatus—Three small boxes.

Materials—Bean seeds, corn seeds.

Procedure—In each of two boxes of clean sand plant a half dozen beans and a half dozen grains of corn. Moisten the sand thoroughly and upon one of the boxes invert a box of the same size and prop it up at one end with an eighth inch block. Put this covered box and the uncovered one side by side in a warm place by a window. Note the plant growth in each from day to day. (Fig. No. 36.)

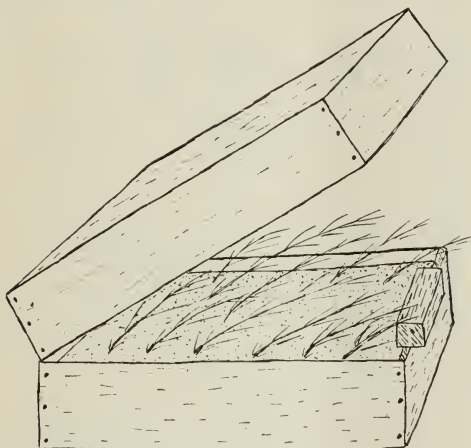


Fig. No. 36. Illustrating study number thirty-one.

Questions—1. Does the seed need light for germination? 2. What sort of growth did the plants in the covered box make? Explain. 3. How long would a plant kept from the light continue to grow?

***Study Number Thirty-two.**

The Plant Upside Down.

Apparatus—Flower pot, or tin can.

Materials—Young growing plant.

Procedure—Plant a young plant in a flower pot by putting the stem and leaves down through the drain hole in the bottom of the pot. Place the pot in a rack with the stem and leaves pointing down and put it where it will receive the light. (Fig. No. 37.) Keep the plant watered and note the growth each day for two weeks. Make four drawings representing the stages of growth in the stem. After two weeks

wash the earth from around the roots and note their direction of growth. Illustrate by drawings.

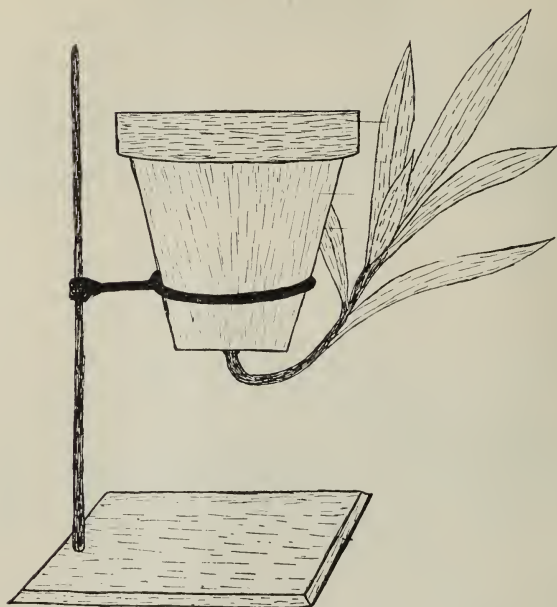


Fig. No. 37. Illustrating study number thirty-two.

Questions—1. What is the direction of stem growth? Of root growth? 2. From past studies explain the conditions you find here.

Study Number Thirty-three.

The Leaf.

Apparatus—Bunsen burner, half dozen test tubes, mortar, water glass.

Materials—Iodine crystals, grain alcohol, cooking starch, a few grains of corn, a green leaf that has been recently taken from the sunlight, wood alcohol.

Procedure—(a) Dissolve several of the iodine crystals in a test tube of grain alcohol. Heat to the boiling point a few grains of starch in a test tube of water. Add a few drops of iodine to the starch water. Note results.

(b) Grind up a few grains of corn in the mortar and treat as you treated the starch above. Note results.

(c) Partly fill a test tube with wood alcohol. In the alcohol submerge a green leaf. Set the test tube aside and leave it until the green color of the leaf disappears. Grind the leaf to pulp and place it in a test tube of water, heat to the boiling point and test the water and leaf with iodine. Note results.

(d) Take a leaf from a plant that has been in the dark for several days. Treat as you treated the leaf above. Note results.

Questions—1. What took place when the iodine solution was added to water containing starch? 2. What did the iodine test show present in the corn grain? 3. What did the iodine test show for the leaf soaked in alcohol in (c) and (d)? 4. What is the function of this green coloring matter that the alcohol dissolved from the leaf? 5. What is this coloring matter called? 6. When is it performing its function?

Study Number Thirty-four.*The Leaf—Continued.**

Apparatus—Glass funnel, water glass, test tube, two quart jars, two pie tins.

Materials—Some green growing water plant, two candles.

Procedure—(a) Put the water plant in a tumbler of water. Over the plant place a funnel. Over the upper end of the funnel invert a test tube completely filled with water. Place this apparatus in the sunlight. (Fig. No. 38.) Note bubbles rising

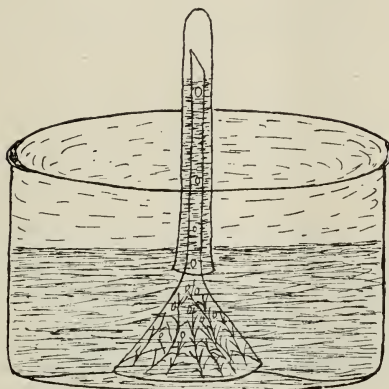


Fig. No. 38. Illustrating study number thirty-four (section A).

from the green plant. When the gas fills the test tube, test it with a glowing splinter. Note results.

(b) Invert two quart jars over a burning candle floating upon a flat cork in a pie tin of water. When the candles have burned out slip a leaf beneath one jar, removing candle. (Fig. No. 39.) Do not lift the jar above the level of the water

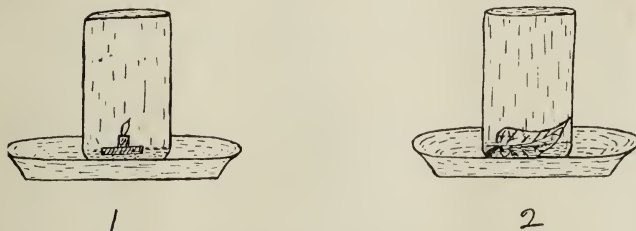


Fig. No. 39. Illustrating study number thirty-four (section b).

in doing this. Set the apparatus aside in a light place and leave for twenty-four hours. Raise the jars carefully and slip a lighted candle under each. Note results.

Questions—1. What was the gas in the test tube? 2. Where does the water plant get its oxygen and carbon dioxide for growth and life processes? 3. When the candle ceases burning under the inverted glass jar what does the air lack? 4. What did you find, after twenty-four hours, in the glass inverted over the leaf? Tell how these conditions came about.

Study Number Thirty-five.*The Leaf—Continued.**

Apparatus—Test tubes, Bunsen burner.

Materials—Green leaves, cotton, paraffine.

Procedure—(a) Dip the broken end of the stem of a green leaf into melted paraffine or candle drip. Roll the leaf and place it in a test tube.



Fig. No. 40. Illustrating study number thirty-five (Section A, 2d part).

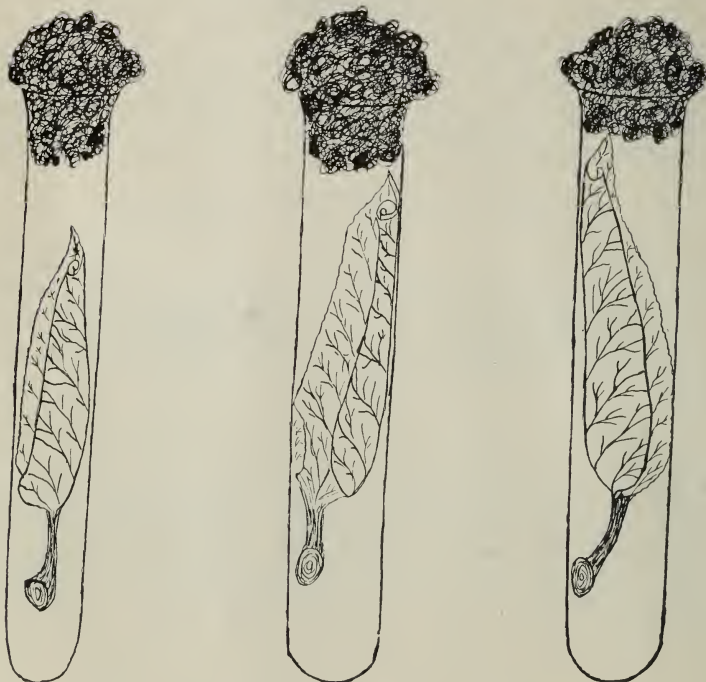


Fig. No. 41. Illustrating study number thirty-five. Section B.

Plug the test tube with cotton and lay it in the sunlight. Or dip the stem end of a half dozen leaves in candle drip and place them under an inverted glass in the sunlight. (Fig. No. 40.) Note results.

(b) Take three leaves and dip the stem of each in melted paraffine. Paint the upper side of one leaf with vaseline and the under side of the other; leave the third leaf as it is. Roll and place each in a separate test tube. Plug the test tubes with cotton. (Fig. No. 41.) Put each in the sunlight. Note results.

Questions—1. In each case what took place in the test tube? 2. Which leaf gave off the most moisture? Which the least? Explain. 3. What is the process of giving off water vapor called? 4. Why is this process necessary?

General Questions—1. What different things, and under what conditions for each, does the growing leaf give off? 2. What does the growing leaf use? 3. What becomes of the food material that the leaf manufactures? 4. What are the two sources of plant food? 5. From which source is the most obtained? 6. Why is it that the plant food supply in the air is not exhausted?

Study Number Thirty-six.

The Plant Gets Food From the Air.

Apparatus—Test tube, Bunsen burner.

Materials—Small branch of a tree; nitric, hydrochloric and sulphuric acid.

Procedure—Secure a branch of a tree a half inch in diameter. Cut off a few short pieces and place them in a test tube. Heat the test tube until all water and smoke is driven off. When heating do not allow the wood to blaze. Take the material that is left after smoke ceases to come off and attempt to dissolve it in cold water, in hot water. Try to dissolve it in weak acids.

Questions—1. What was the color of the material left in the test tube? What was it? 2. Could you dissolve this in water or in weak acid solutions? 3. Could the soil water dissolve this material? 4. How did this material get into the plant structure?

*Study Number Thirty-seven.

To Show Transpiration.

Apparatus—One wide mouthed bottle, cork to fit bottle, knife, scales and weights.

Materials—Young plant, as cabbage or some weed; candle or paraffine.

Procedure—Secure some single stemmed young growing plant, as a cabbage or some young weed. Take precaution to get as much of the young root system as possible.

Place the roots of this plant in a wide mouthed airtight bottle three-fourths full of water, either well water or that secured from a stream or irrigation ditch. To do this take the cork and bore a hole through the middle large enough to accommodate the stem of the plant and then split the cork from one side to this hole. (Fig. No. 42.) Through this split place the cork around the plant and with it cork the bottle tightly in such a manner that the roots are well in the water. To make the bottle airtight fill in the split and the hole around the plant with melted paraffine or the drip from a burning candle. Hold the burning candle well above the plant and apply the drip slowly, drop by drop. Turn the bottle upside-down to see if any water escapes; if so apply candle drip at the points of escape until you are sure that the bottle is airtight.

Take the weight of the bottle and the next morning place it in the sunlight. Take its weight every day for two weeks.

Questions—1. Does the bottle decrease in weight? 2. What does this decrease show? 3. How did the water leave the bottle? 4. What weight of water has the plant used? 5. Has the plant made any growth? If so, where did it get material for growth? 6. Under natural conditions, of what use is the water obtained from the soil to the plant?

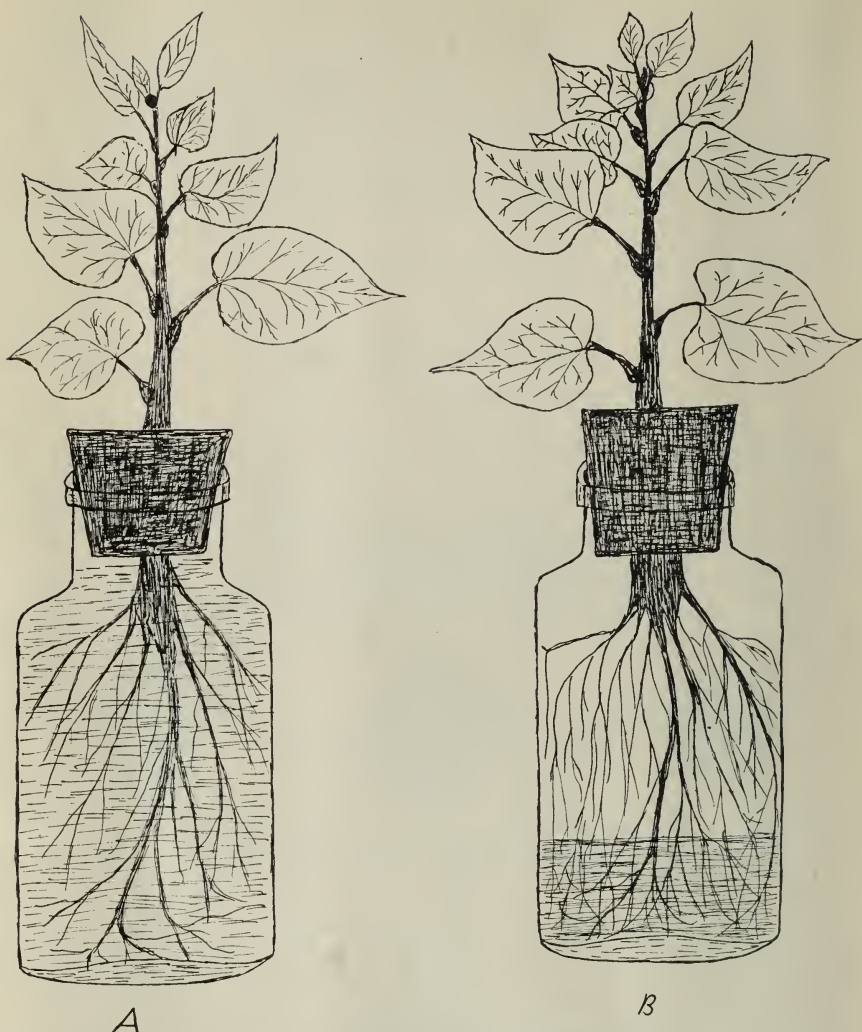


Fig. No. 42. Illustrating study number thirty-seven.
 A—Bottle filled with water and made air tight.
 B—Same bottle two weeks later.

Study Number Thirty-eight.

Structure of the Leaf.

Apparatus—Microscope, dissecting tools.

Materials—Green leaves of some young plant.

Procedure—Make a cross section slide of the leaf and examine it under the microscope. Draw the slide as seen, labeling the chlorophyll bodies, starch grains, epidermal cells, pyramidal cells, intercellular tissue, and stomato.

Questions—1. What are the functions of each of the following: stomato, epidermal cells, pyramidal cells, intercellular spaces, starch grains, chlorophyll bodies and intercellular tissue?

Study Number Thirty-nine.*The Buds.**

Apparatus—Knife, lens, water glass, mosquito netting, rubber band.

Materials—Dormant branches of several types of trees, branches of several types of trees in full leaf, a potato, some wheat seed, some geranium branches, roots of the Shasta daisy or a sweet potato.

Procedure—(a) Take the dormant branches at hand. Make a drawing of each, indicating lateral buds, terminal buds and accessory buds, and little clusters of partial rings at intervals along the branches.

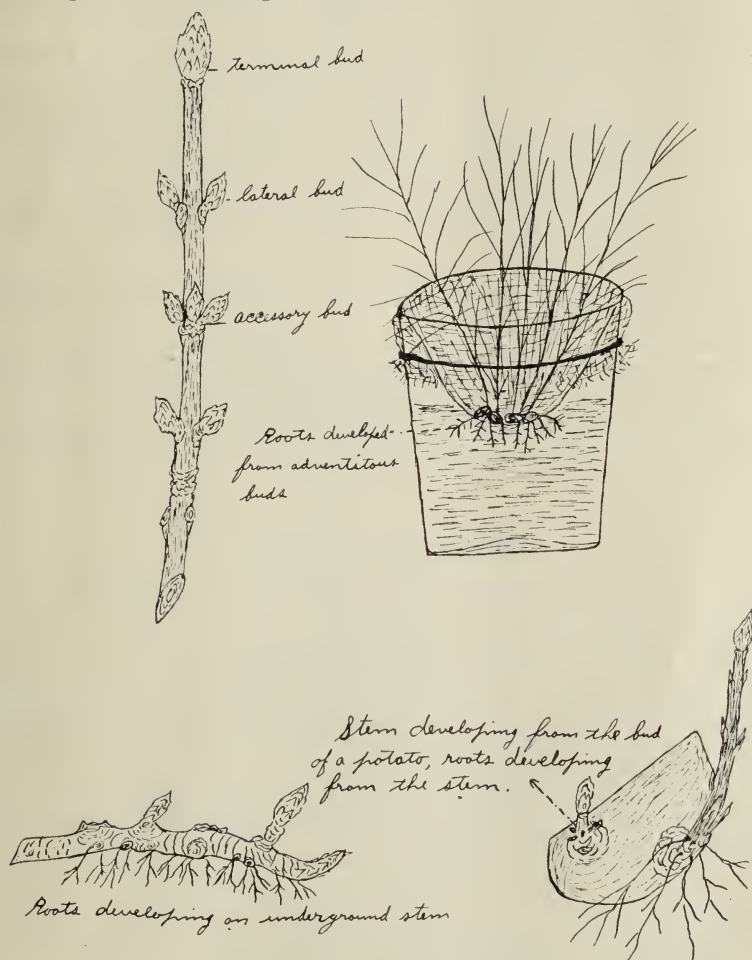


Fig. No. 43. Illustrating study number thirty-nine.

Questions—1. How old is each branch? 2. How can you tell its age? 3. What caused the little clusters of partial rings? 4. What then does each cluster of rings represent?

(b) Take the branches bearing leaves. Look for axillary buds. Indicate by drawing axillary and terminal buds. Note the difference in the bud development of the current year's growth and the past year's growth. (Fig. No. 43.)

Questions—1. How do you account for the differences in bud development found above? 2. What are some of the buds upon the older wood developing? 3. What

has become of those missing from the older wood? 4. Where do you find the buds upon the current year's growth?

(c) Secure branches of some of the common fruit trees, if in bloom, and note the position of leaf buds and fruit buds. Indicate them by a drawing.

Questions—1. Where do you find most of the fruit buds? Most of the leaf buds?

(d) Take the potato and find and examine the buds. Cut the potato in two pieces and plant them in damp sand. Watch the development of stem, leaves and roots. Illustrate by drawings.

Questions—1. From what did the stem develop? The leaves? 2. From what did the roots develop? 3. What sort of buds formed the roots?

(e) Make and plant some geranium cuttings. Watch them for the development of roots, stems and leaves. Illustrate by drawings.

Questions—1. From what part of the geranium do the stem and the leaves come? The roots? 2. What sort of buds developed the roots?

(f) Plant, in damp sand, a portion of a Shasta daisy root or a sweet potato. Note the development of roots, stem and leaves. Illustrate by drawings.

Questions—1. What sort of buds developed the stem and leaves? 2. What sort of buds developed the roots?

(g) Place some grains of wheat on a mosquito netting suspended in a glass of water. After the wheat has made some growth cut the roots back and note the development of the new roots.

Questions—1. From what part of the plant did the original roots develop? 2. From what part did the second growth of roots develop? 3. From what sort of buds did the second growth develop?

(h) Secure, examine, and illustrate by drawing covered buds and naked buds.

General Questions—1. What do you understand by bud propagation? 2. Name several methods of bud propagation. 3. Why is bud propagation used? 4. For successful budding of fruit trees what type of bud must be used? 5. Why do not trees from seeds, as from buds, always grow the same type of fruit as the parent tree?

*Study Number Forty.

The Upward Passage of the Soil Solution in the Plant.

Apparatus—Eight ounce wide mouth bottle.

Materials—Red ink, young plant grown in the dark.

Procedure—Fill the bottle three-fourths full of water. Color the water with a half dozen drops of red ink. Carefully remove the young plant from the soil, getting as many roots as possible. Gently shake the plant to remove most of the adhering soil and place the roots in the red ink solution. Set the bottle in a warm dark place and after twenty-four hours examine the plant.

Questions—1. What took place in the plant? 2. By what processes does the plant take water to all of its parts? 3. Any plant food in the soil to be available for plant use must possess what property?

*Study Number Forty-one.

The Stem.

Apparatus—Jelly glass, knife.

Materials—Stems of calla lily and sweet pea with flowers attached, stalk of corn, branch of a hardwood tree, bottle of red ink.

Procedure—(a) Color a glass of water with a few drops of red ink. In the glass place a stem of the calla lily and the sweet pea. Set the glass aside and several

hours later examine the flowers. Cut the stem of the lily lengthwise and trace out the red lines that you find. Draw a diagram of the stem and flower showing the red lines as you see them. (Fig. No. 44.)

(b) Make a cross section and a longitudinal section of a cornstalk and draw each. Do the same with a hardwood stem. Point out and label the types of tissue composing each stem.

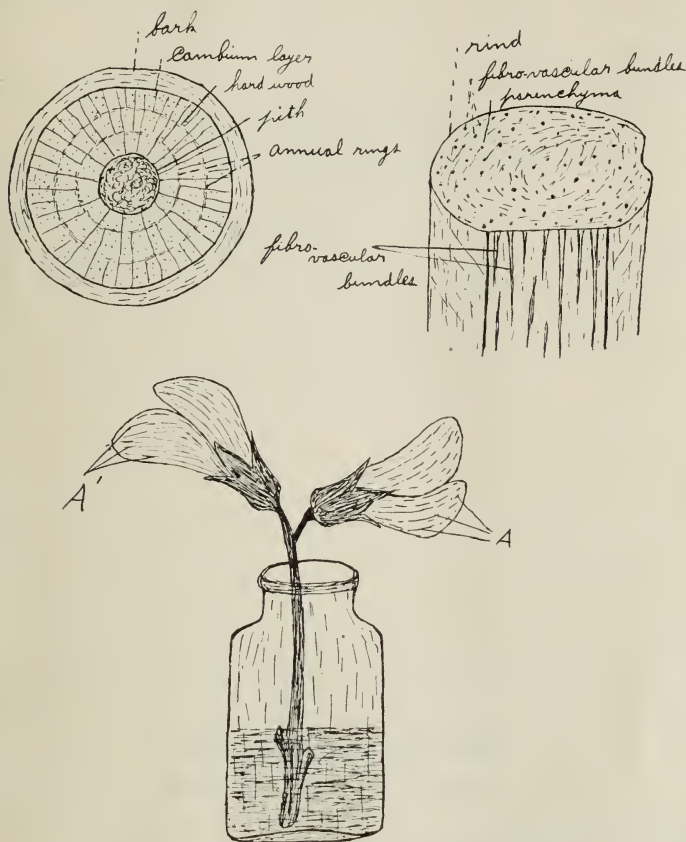


Fig. No. 44. Illustrating study number forty-one.
A and A'—Red ink in the fibro-vascular bundles in the petals of a white sweet pea.

(c) Collect from the campus and garden a number of stems and group them into classes represented by the cornstalk and the hardwood stem.

(d) Draw a cross section of a hardwood tree several years old and label all parts.

Questions—1. What are the functions of the stem? 2. By what processes did the colored water get from the glass to the flower? 3. Through what did this water pass? 4. How can you tell the age of a tree? 5. How are the rings developed? 6. What is the function of each stem part here mentioned: bark and rind, cambium tissue, sieve tubes, medullary rays, parenchyma tissue, fibrovascular bundles and hardwood tissue?

Study Number Forty-two.

Some Stem Types.

Materials—To be secured.

Procedure—Take a field trip and find and make drawings of the following types of stem: deliquescent, excurrent, trailing, creeping, decumbent and two types of climbing stems.

Questions—1. What are the functions of the stem? 2. What do you understand by a modification or reduction of the stem? Have these characteristics benefited the plant? 3. In what way are stems and stem parts used in plant propagation? What is the advantage of this sort of propagation over seed propagation?

Exercise—Fill in the following table of stem products and tell which of these you consider the most valuable to mankind, and why:

Stem Products	The Source of Supply
Food (three)	
Linen	
Lumber (six)	
Sugar sap	
Cork	
Fuel (six)	
Hemp	
Tannin	
Turpentine	

*Study Number Forty-three.

The Needs of the Growing Plant.

Apparatus—Flower pots.

Materials—Box planted to young plants.

Procedure—(a) Place a young potted plant where it will get plenty of sunlight and withhold the water from it until it is quite badly wilted. Water thoroughly and note results.

(b) Submerge entirely the pot in which a young plant is growing and keep it thus for two weeks. Note the condition of the plant from day to day.

(c) Submerge a flower pot, in which is growing a young plant, up to the rim in a pan of warm water. Place a second flower pot, as above directed, in a pan of melting ice and water. In a short time contrast the rigidity of stem and leaves of the two plants.

(d) Put a potted plant in a cool place, put one where it is dark but warm, put one where it is light and warm. In each keep the soil moist. Observe daily and note growth and changes of each.

(e) Paint the leaves and stems of a young plant thoroughly with melted vaseline. Give the plant ideal growing conditions.

Questions—1. What happened to the wilted plant studied in section (a) when watered? 2. What gives a green plant its rigidity? 3. What happened to the plant whose roots were submerged in water? 4. What was the cause of this? 5. What brought about the conditions observed in the two plants contrasted in the study of section (c)? Those studied in section (d)? That studied in section (e)? 6. What are good conditions for a growing plant?

Study Number Forty-four.

Water, Dry Matter and Ash in Plants.

Apparatus—Scales, weights, test tubes, crucibles.

Materials—A green growing plant, dry hay.

Procedure—Weigh two thoroughly dried test tubes. In one place a young green plant and weigh again. In the other place some dry hay and weigh again. Place these in the drying oven and heat for twenty-four hours at a temperature of 98° C. Reweigh each tube. The above treatment has driven off the water.

Burn the plants by heating very hot in a previously weighed porcelain crucible until only a light gray ash remains. Reweigh. The difference between the weight of the ash and the dried plants is the weight of the dry matter.

Record as follows:

Weight of test tube.....
 Weight of test tube and plant.....
 Weight of plant.....
 Weight of dried plant.....
 Weight of ash.....
 Per cent of water.....
 Per cent of dry matter.....
 Per cent of ash.....

Questions—1. To what uses is the water put in the plant body? 2. What composes the ash of the plant? 3. How and where did the plant get the material composing the ash? 4. What was the source of most of the material composing the dry matter? 5. What part of the plant body is of most food value to the animal, the water, dry matter or ash? 6. Were the green plant alfalfa, how many tons would it take to make a ton of dry hay?

NOTE.—Turn back to Study Number One and complete the work called for in the last part of that study.

*Study Number Forty-five.

Green Cuttings.

Apparatus—Sharp knife.

Materials—Geranium branches, carnation, begonia, etc.

Procedure—Cut off about three to four inches of the ends of the branches. This tip should possess five or six leaves. Cut away all but the upper two leaves. Cut

these back to about one-fourth of the original surface. The remainder of the branch can be treated similarly and the other branches can be made into cuttings in the same manner. (Fig. No. 45.)

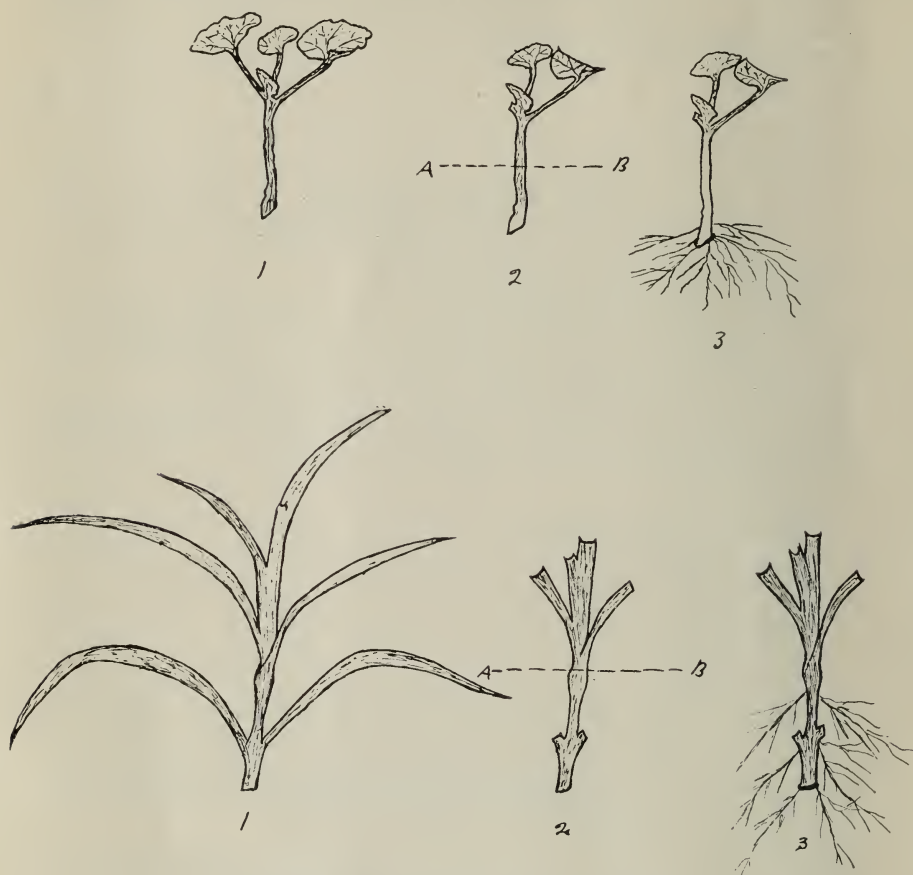


Fig. No. 45. Illustrating study number forty-five.

- 1—Sprays of the geranium and carnation taken for cuttings.
- 2—Cuttings ready for setting in sand, line A—B shows depth of planting.
- 3—Cuttings well rooted.

When the cuttings are made, plant them in the sand with the leaves about an inch above the surface.

Questions—1. What are the advantages of making cuttings to grow new plants over the use of seeds? 2. Can cuttings be made of all kinds of plants? Why not?

*Study Number Forty-six.

To Make Hardwood Cuttings.

Apparatus—Knife, string.

Materials—Dormant branches of the grape, currant, raspberry, poplar, rose, willow, etc.

Procedure—Make the cuttings of each by cutting the branches into pieces about eight inches long, having at least three buds attached. Use a pair of pruning shears or a sharp knife and make a smooth, clean cut diagonally across the stem in a position that the bud both at the top and the bottom of the cutting is an inch from the cut surface. (Fig. No. 46.) Heal the cuttings in damp sand until early spring.



Fig. No. 46. Illustrating study number forty-six.

1—Ordinary cutting. 2—Heel Cutting. 3—Mallet cutting. 4—Grape cutting well rooted. Line A-B shows depth of planting.

Questions—1. Why make the cut an inch from the bud in making cuttings? 2. Why do hardwood cuttings do best when healed in damp sand instead of being planted out immediately after made? 3. Why is it often more profitable to propagate by cuttings than by seed? 4. Why is it best to make hardwood cuttings in the late fall or early winter?

*Study Number Forty-seven.

Struggle for Existence.

Materials—Ear of corn, spike of wheat, or a weed (cocklebur) growing many seeds.

Procedure—Count all of the seeds on the grain plant chosen and all of the seeds on the cocklebur. Begin with one seed for each plant and allow that that seed produce the number of seeds that you have counted for each plant above. Now suppose that all of these seeds grew the next year and each seed produced as many seeds as did the first seeds, and so on for five years.

Questions—1. How many plants of each type will be growing the fifth year? 2. Why do not conditions supposed above come to pass? 3. If the cocklebur plant produced by the first seed occupied to the exclusion of other plants a plot of ground 2' 8" by 3' 4" square and all of the succeeding plants occupied the same area, how many acres of ground would the offspring from the one original seed have occupied in five years?

Study Number Forty-eight.*Struggle for Existence.**

Apparatus—Foot rule, knife, notebook.

Materials—To be found.

Procedure—Take the class to a weed patch or some place where vegetation is growing thickly under natural conditions. Have each student measure off an area two feet square. Count the approximate number of plants growing on this area and group them as vigorous, medium vigorous, weak, very weak.

Find a fruit tree, an apple, plum, peach or almond. Count the number of buds and twigs or blossoms and twigs on a limb of the tree. Note the growing conditions for all and class them as good, fair or poor.

Questions—1. How many plants did you find on the area of two feet square? 2. What per cent of them give indications of maturing and developing vigorous seed? 3. What per cent of buds or blossoms studied will produce well developed fruit or vigorous twigs? 4. What per cent of the twigs will develop into branches? 5. Which plants and plant parts survive under natural conditions? 6. What would happen to our present cultivated plants if left to natural conditions?

Study Number Forty-nine.*Variation in Plants.**

Apparatus—Scales and weights, foot rule.

Materials—Branches and leaves of some tree, several stalks of wheat.

Procedure—Take a branch of a tree and attempt to find two leaves that are alike. Select the two leaves that seem the most alike and compare them in minute detail and note differences. This can best be done by making a list of the leaf characteristics and noting how they differ in these characteristics.

Select two very similar stalks of wheat. Compare them and note differences as follows: Number of leaves, number of spikelets, length of spike, length of stalks, diameter of stalks, length of corresponding internodes, shape of leaves, number of grains of wheat in each spike, total weight of grain in each spike, total weight of each stalk and leaves, total weight of each plant, stalk, leaves, grain and all.

Questions—1. To what conclusion do the above studies bring you? 2. What opportunity does the condition you found in plants give the grower of plants for plant improvement? 3. Were all plants identical would it be possible to improve them? Explain.

Study Number Fifty.*Dispersal of Seeds.**

Procedure—Take a short field trip. Collect plants bearing seeds and note under which class it would come for seed dispersal. Dispersal by wind, water, animals or plant mechanisms.

Make a drawing of several types of plants and of seeds in each class, and give a short description of the process of seed dispersal.

Questions—1. What part does the method of seed distribution play in the struggle for existence? 2. In a given length of time, which would scatter the farthest, trees like the oak or the poplar?

Study Number Fifty-one.*Seed Germination Test.**

Apparatus—Six small plates or pie tins; blotting paper.

Materials—Six seed samples, water.

Procedure—Take a sample of several different kinds of seeds, as clover, alfalfa, wheat, cabbage, radish, etc., and from each sample count out a hundred seeds. This done, get a plate or a pie pan and cover the bottom of it with blotting paper. Thoroughly moisten the blotting paper and upon it sprinkle the sample of 100 seeds; over the seeds place a second sheet of blotting paper. Over this plate lay a piece of glass or an inverted pie tin and place it in a warm place. Apply water often enough to keep the blotter moist. When the seeds begin to germinate count out each day and throw away those that have germinated. Do this until you are sure that the remaining seeds will not germinate.

Record as follows:

Total number of seeds_____

Number of seeds that germinated_____

Number of seeds that did not germinate_____

Per cent of germination_____

- *Questions and Problems*—If the alfalfa seed tested sold at \$16.50 per hundred-weight, what was the actual cost of the seed that germinated?

If you were sowing the alfalfa seed tested at the rate of eight pounds per acre, what per cent would the seeding fall short of growing a perfect stand of alfalfa?

If you were sowing the wheat tested above at the rate of 85 pounds per acre, what per cent would the seeding fall short of growing a perfect stand?

What could be done to bring the stand up to normal in each case given above?

Study Number Fifty-two.*Seed Analysis.**

Apparatus—Scales and weights, small plate, blotting paper.

Materials—Sample of dirty impure seed, water.

Procedure—Secure a sample of unclean clover seed or alfalfa seed. Weigh out one gram of the seed and then separate it into (1) pure seed, (2) broken seed, dirt, etc., (3) weed seed. Weigh again. Make a germination test of the pure seed as directed in Study Number Fifty-one.

Record results as follows:

Weight of seed sample_____

Weight of pure seed_____

Weight of weed seed, dirt, etc._____

Per cent of purity_____

Per cent of germination_____

Questions—1. If the price of the original seed was \$12.50 per hundred, what was the cost of the pure seed that germinated? 2. Why would it not be wise to sow impure, dirty seed?

Study Number Fifty-three.*Depth of Planting Seeds.**

Apparatus—Glass jar.

Materials—Seeds of corn, radish and clover, sand.

Procedure—Put a little sand in the jar and on it next to the glass place several seeds of each type mentioned above. Put in another inch of soil and then more seeds as above. Continue this until the jar is filled, and plant seed a fourth of an inch under the soil at the top. The jar should be at least six inches deep. Put the jar in a warm place and keep the sand moist. (Fig. No. 47.) Watch from day to day.



Fig. No. 47. Illustrating study number fifty-three.
Corn seed planted to the depth of 2, 4, 6, 8, 10 and 12 inches.

Questions—1. What took place in the experiment above? 2. From what depth did each type of seed make the best growth? 3. Judging from the experiment, what general rule can you give for planting seeds? 4. What is the function of the stored food in the seed? 5. Why is it necessary to get the seed leaves up to the air and light?

Study Number Fifty-four.*Dependent Plants.**

Apparatus—Dissecting tools, microscope and lens.

Materials—Mushrooms and bread mold.

Procedure—(a) Secure a piece of moldy bread. Examine the mold with a hand lens. Look for little upright growth capped with a tiny ball. Examine under the microscope. Draw the slide you have made. Find a little patch of mold where these little balls are black. Examine under the microscope. Draw the slide you have made.

(b) Gather some mushrooms. Make a drawing of a longitudinal section of the mushroom and label the different parts. Paste a mushroom upside down upon a piece of cardboard with library paste and set it aside. Look daily for the development of spores. Illustrate by drawing the development of the spore sacs. Examine some of these spores under the microscope.

Questions—Is the mushroom a plant? Where do you find mushrooms growing? What part of the mushroom bears the spores? What is the function of these spores? How are they scattered? How can you tell dependent plants? Class as parasites or saprophytes the following: mushrooms, mistletoe, dodder, bread mold, wheat rust, potato blight, grape rust, brown rot.

***Study Number Fifty-five.**

Some Injurious Dependent Plants.

Apparatus—Pie tins, pin.

Materials—Eight good apples, 8 good oranges, 4 decaying apples, 4 oranges infected with blue mold.

Procedure—Take a decayed apple and prick the decayed part with a pin and then prick a good apple with the same pin. Repeat this three or four times. Lay the good apple thus treated upon a plate. Take another apple and bruise one side of it by rapping it on the table. Lay it on a plate with the bruised side in close contact with the decaying portion of another apple. With these apples place one that is sound in every respect in close contact with the decaying portion of another apple. Put all in a warm, rather dark place. Take the oranges and treat them as you have the apple above.

Questions—1. Which apple and orange became infected the quickest? 2. Which were last in becoming infected? 3. What care should be taken in picking and packing fruit? 4. Would it pay to sort over occasionally fruit stored for home use? 5. Can apple decay and blue mold be transmitted in any other way than in the examples given above? Explain. 6. Why is it wise to wrap each fruit separately when packing them for shipping? 7. Why are oranges washed in a copper sulphate solution before packing and storing?

Study Number Fifty-six.

Conditions Favoring Bacterial Growth.

Apparatus—Three pint bottles, 3 petri dishes, Bunsen burner, drying oven, refrigerator.

Materials—Quart of milk, nutrient gelatine, sterilized cotton.

Procedure—Divide the milk equally into the three bottles. Label the bottles 1, 2, and 3. Cork No. 1 and place it in a moderately warm room. Cork No. 2 and place it in the refrigerator. Put No. 3 in a pan of water and boil for thirty minutes. Cork the bottle with sterilized cotton and put it with bottle No. 1. After forty-eight hours compare the samples of milk. Note the condition of each, the smell and taste of each.

Put some sterile nutrient gelatine in each of three petri dishes that have been heated in the drying oven at 100° C. for six hours. Label the dishes 1, 2, and 3. Put the covered dishes in a drying oven at 100° C. for one half hour a day for three days. Open dish No. 1 to the air of the room for two minutes. Cover and set in a warm, moist dark place. Examine it every day. Note any effects upon the gelatine.

Put No. 2 where it can receive the direct sunlight the greater part of the day and be left moderately cool. Note results from day to day.

Put No. 3, without the cover, in a very dry place. Note results as above.

Questions—1. What effect have dark warm places upon bacterial growth? Sunlight? Dry conditions? 2. What conditions favor bacterial growth? What retard? 3. Why does food spoil? How can food be preserved?



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